Lake Pepin Watershed Full Cost Accounting Project:

Optimum Landscape Allocation of Conservation Practices for Water Quality and Ecosystem Service Valuation.

wq-ppt2-08

Lake Pepin Watershed Full Cost Accounting Project:

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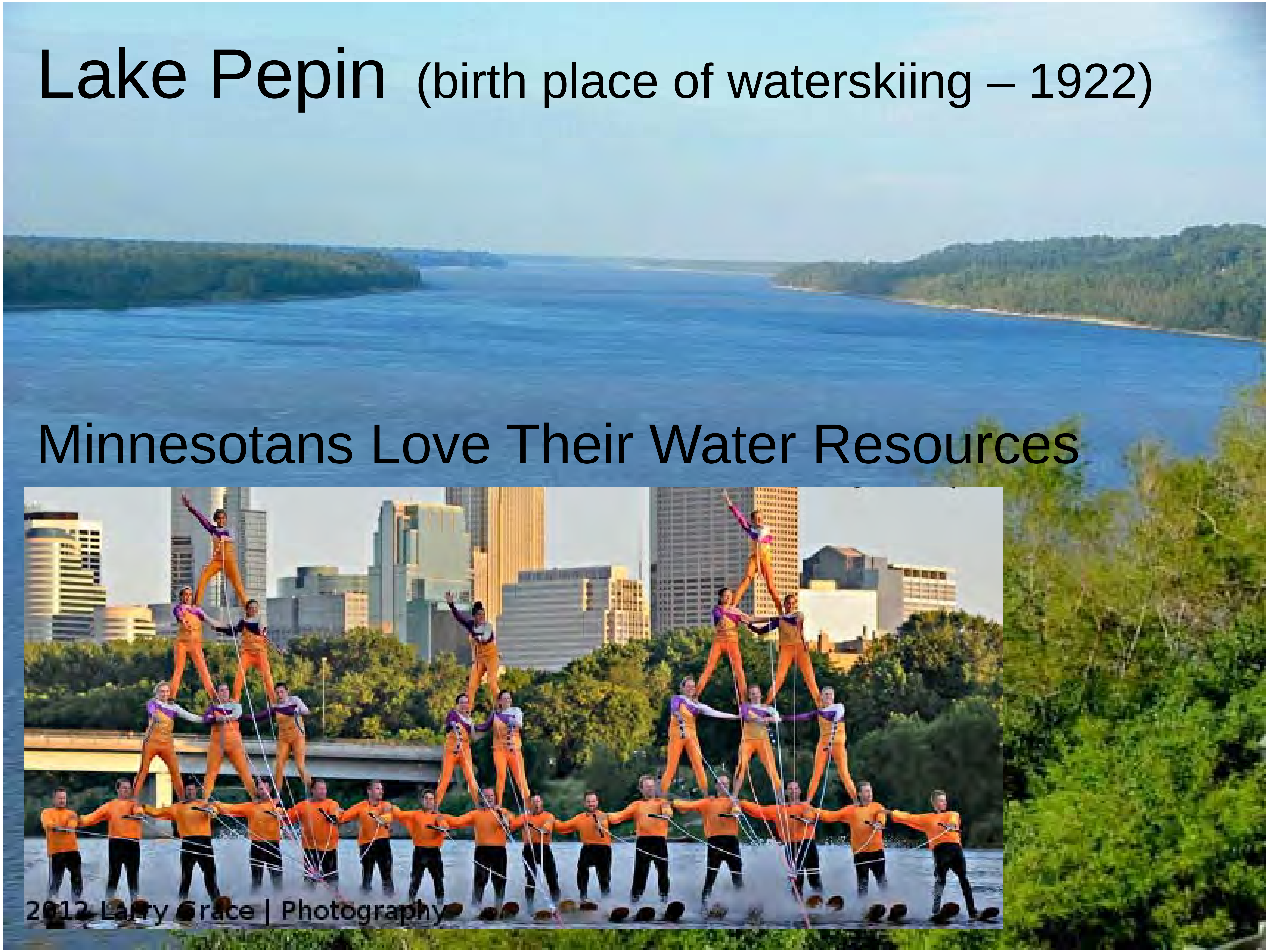
Funding: Minnesota Pollution Control Agency


Lake Pepin (birth place of waterskiing – 1922)
Minnesotans Love Their Water Resources
2012 Larry Grace | Photography

Lake Pepin Watershed

Lake Pepin Basins

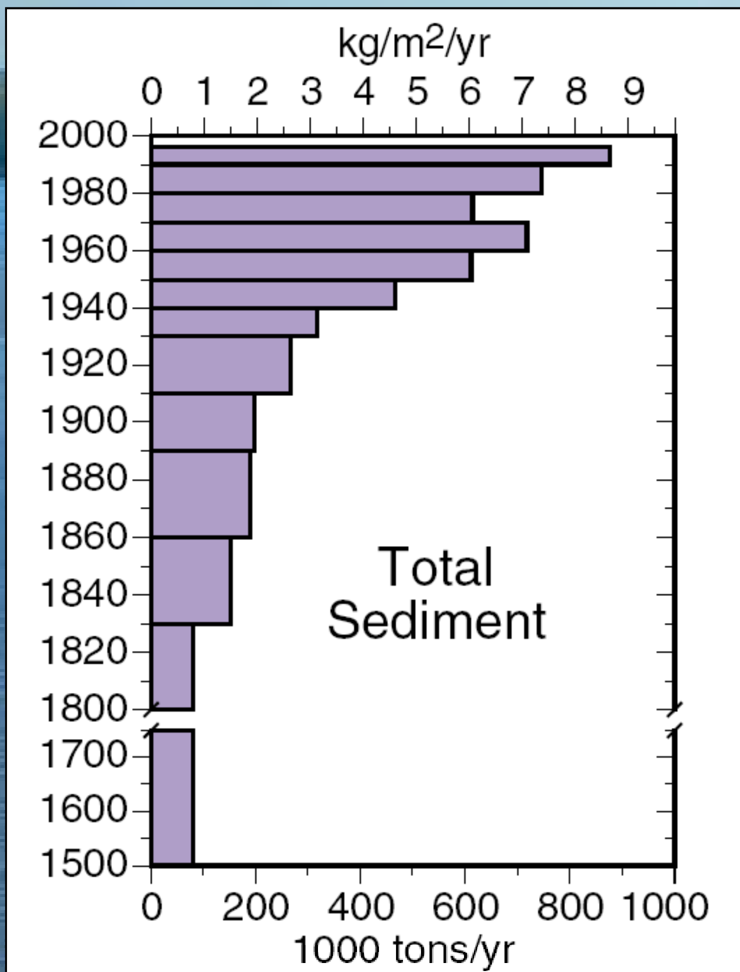
BASIN

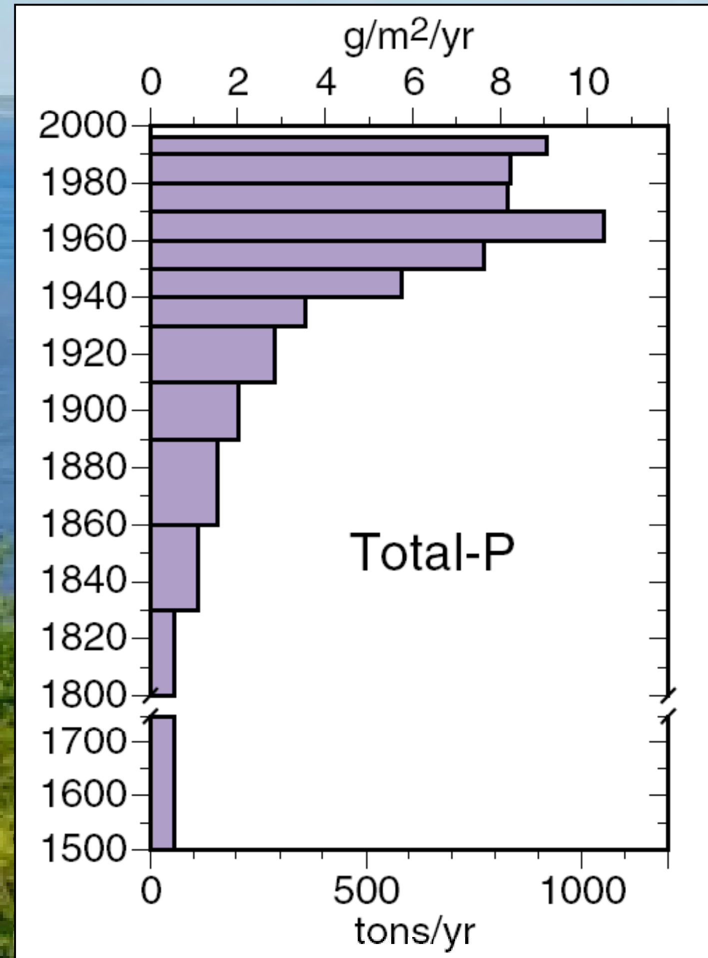
- Cannon River Basin
- Minnesota River Basin
- St. Croix River Basin
- Upper Mississippi River Basin
- HUC 07040001
- Major Rivers
- Metro Area

Feature	Area (Kilometers^2)
Lake Pepin Watershed	122,575
Minnesota	218,480
Lake Pepin Watershed with in Minnesota	105,368

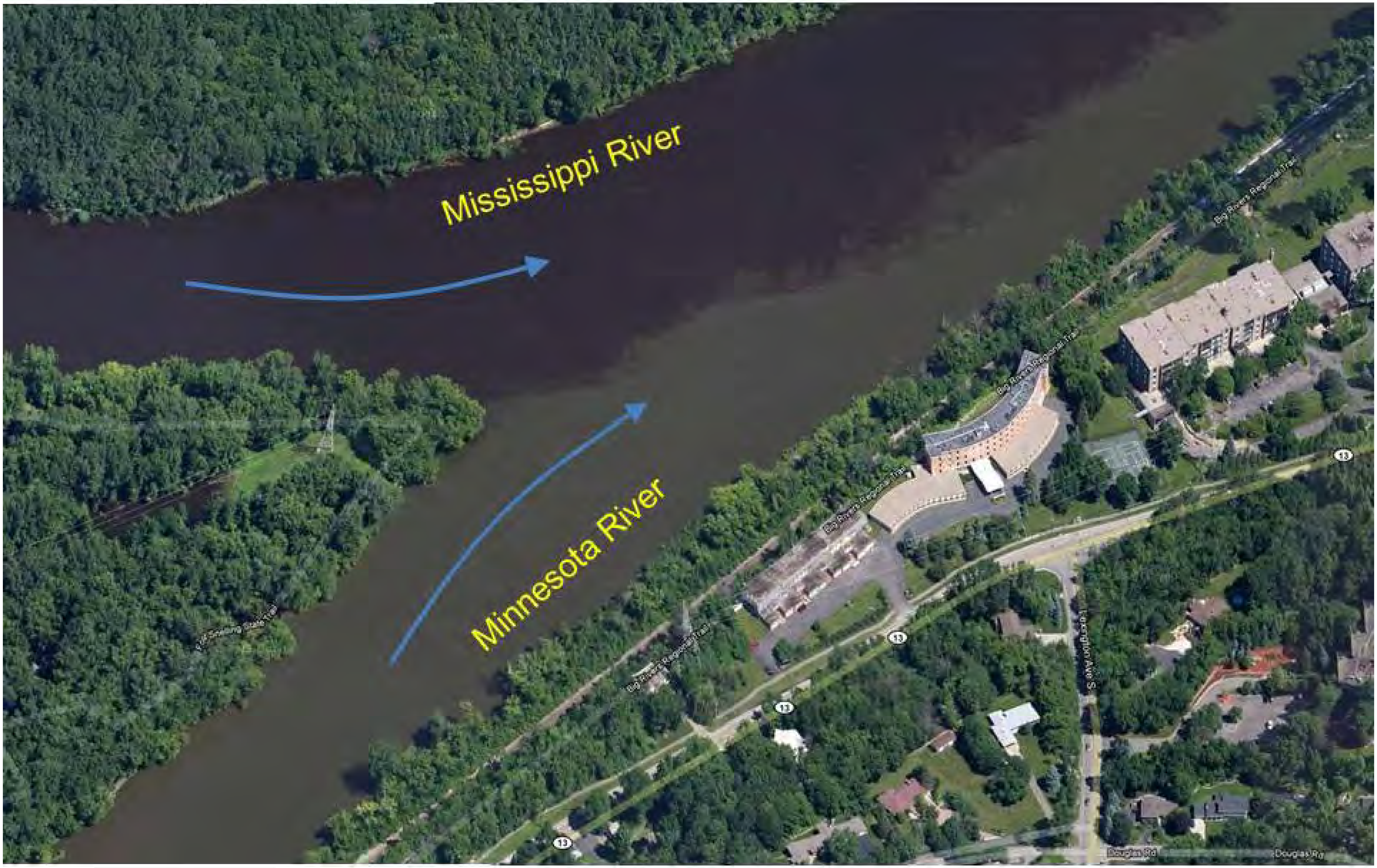
Minnesota Pollution Controal Agency

Sediment and phosphorus loading to Lake Pepin is occurring at an accelerated rate





SCWRS Fact Sheet 2002-02; (Engstrom and Almendinger)

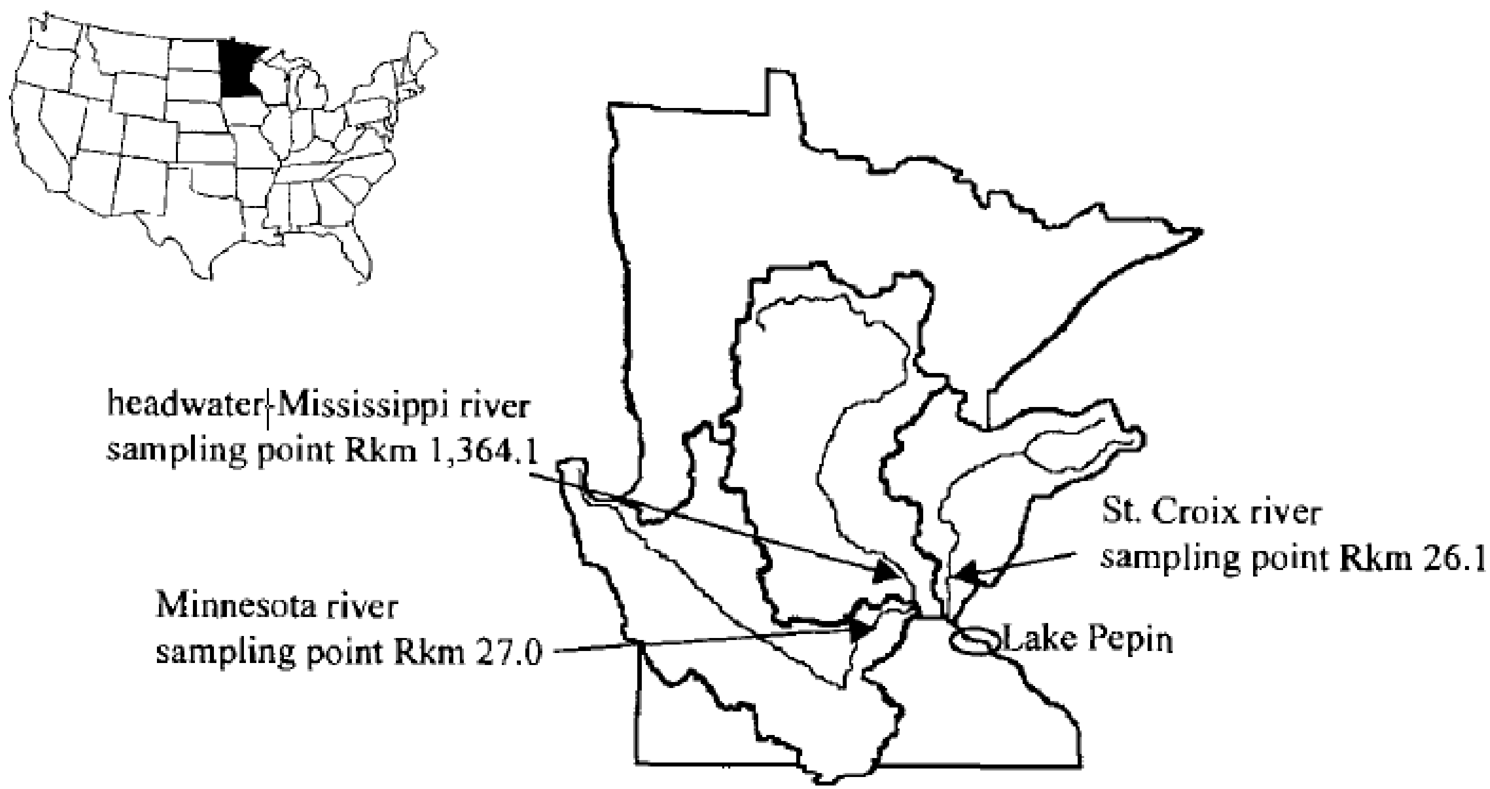


introduction

Lake Pepin TMDL: What's the problem?

Kelley and Nater, 2000.

J. ENVIRON. QUAL., VOL. 29, MARCH–APRIL 2000



- Minnesota River has always been a disproportionate source of sediment to Lake Pepin but its role has increased:

- 87 to 90% of the current sediment load originates in the MN River Basin.

TMDL Goal

- The Lake Pepin TMDL is expected to require from 25 to 50% reductions of P and sediment from current levels
- MPCA is obligated (Minn. Stats. 114D.25) to expand the scope of its TMDL analyses:
  - Examine the impacts of meeting TMDL goals on the area's water quality, carbon budget, habitat, and agricultural production
  - Estimate economic benefits and costs associated with attainment of water quality standards resulting from changes in management in the Lake Pepin watershed

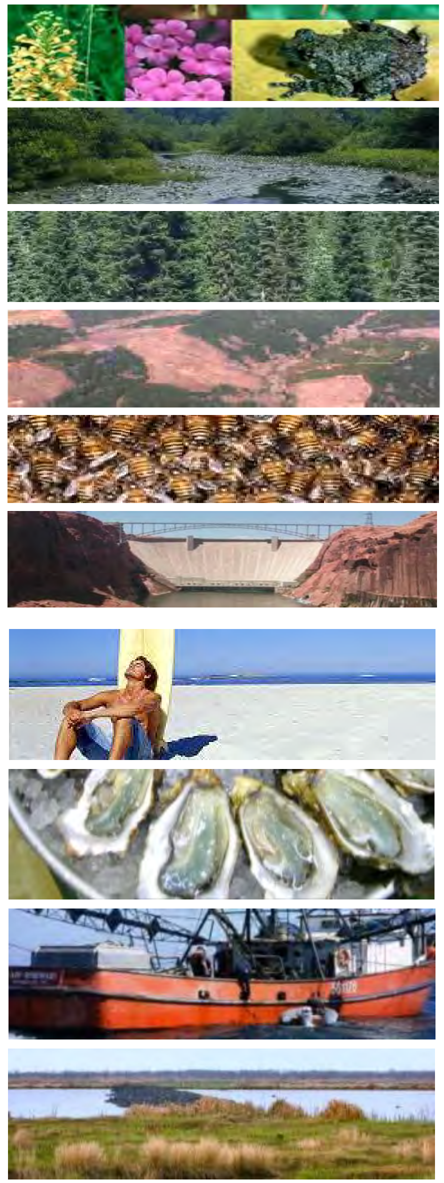
How To Meet TMDL Goals?

- There are many potential changes in land use and land management that could meet TMDL goals
- We are assessing alternative land use/management scenarios to achieve water quality improvements
- Developing a comprehensive assessment of the net economic benefits associated with alternative scenarios for achieving TMDL goals

Marine & Terrestrial Ecosystem Services

natural
capitol
PROJECT

- ***Ecosystem services*** are the contributions of nature to the provision of goods and services that contribute to human well-being
  - Provisioning (food, fuel, fiber…)
  - Regulating (carbon sequestration, water quality…)
  - Cultural (aesthetics, recreation…)



Marine & Terrestrial Ecosystem Services

natural
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PROJECT

Recreation

Aquaculture

Fisheries

Coastal Protection

Wave Energy

Aesthetic Quality

Water Quality

Habitat Quality

Carbon Sequestration

Sediment retention

Water purification

Crop pollination

Hydropower

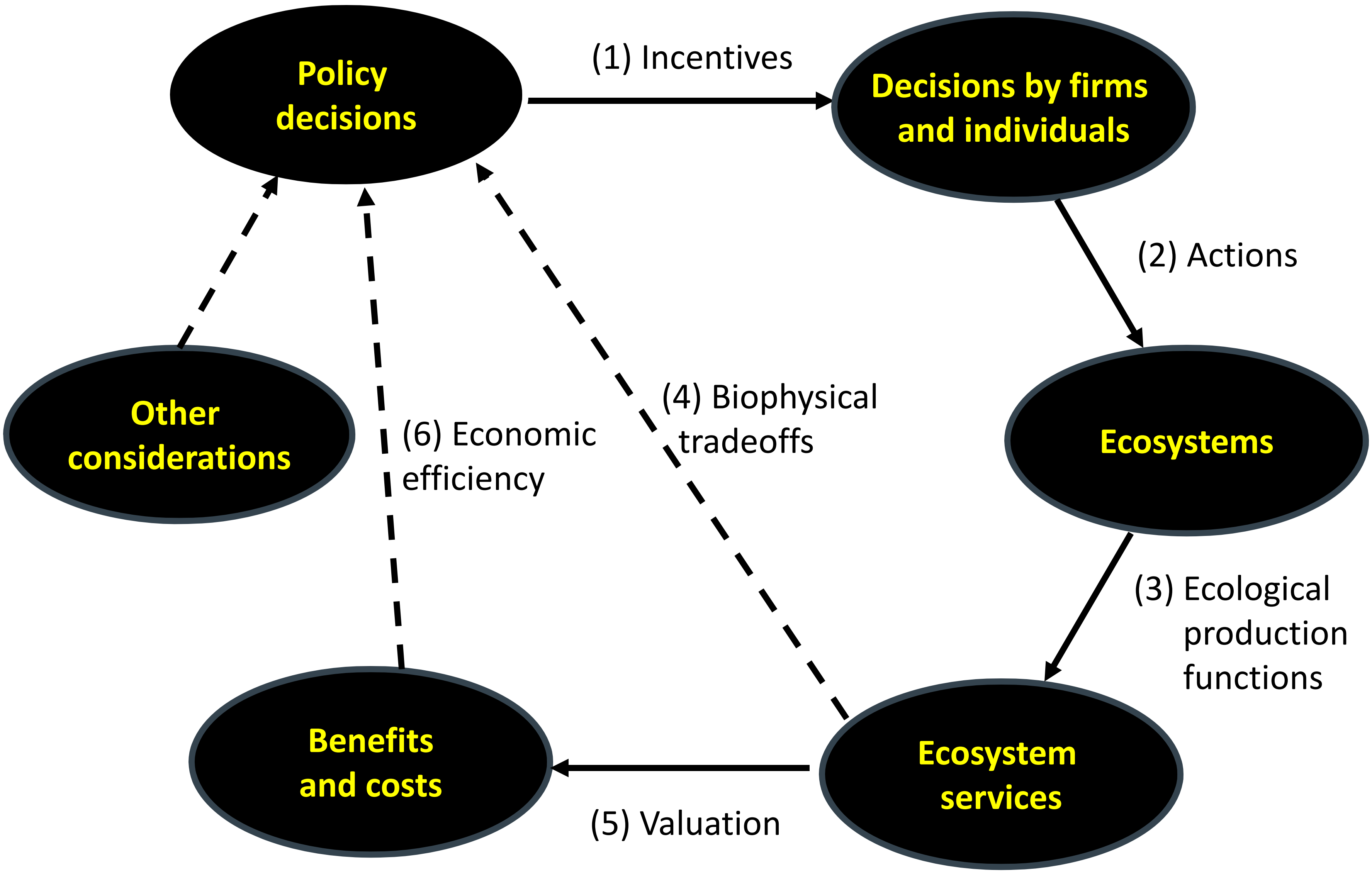
Agricultural prod’n

Irrigation water

Commercial timber

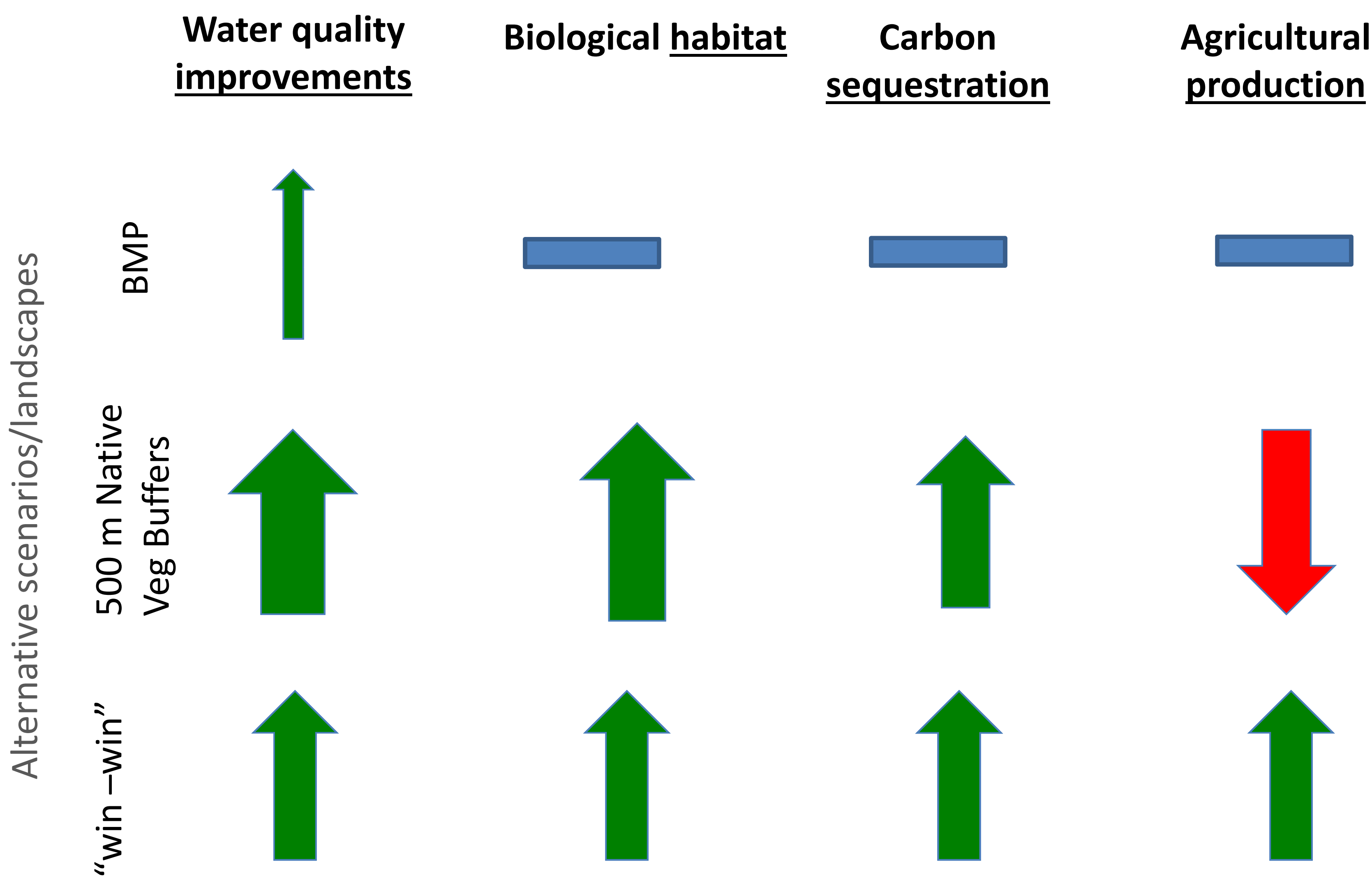
Flood control

Schematic of ecosystem services research



Polasky & Segerson *Annual Review of Resource Economics* 1: 409-434.

Evaluating Trade Offs

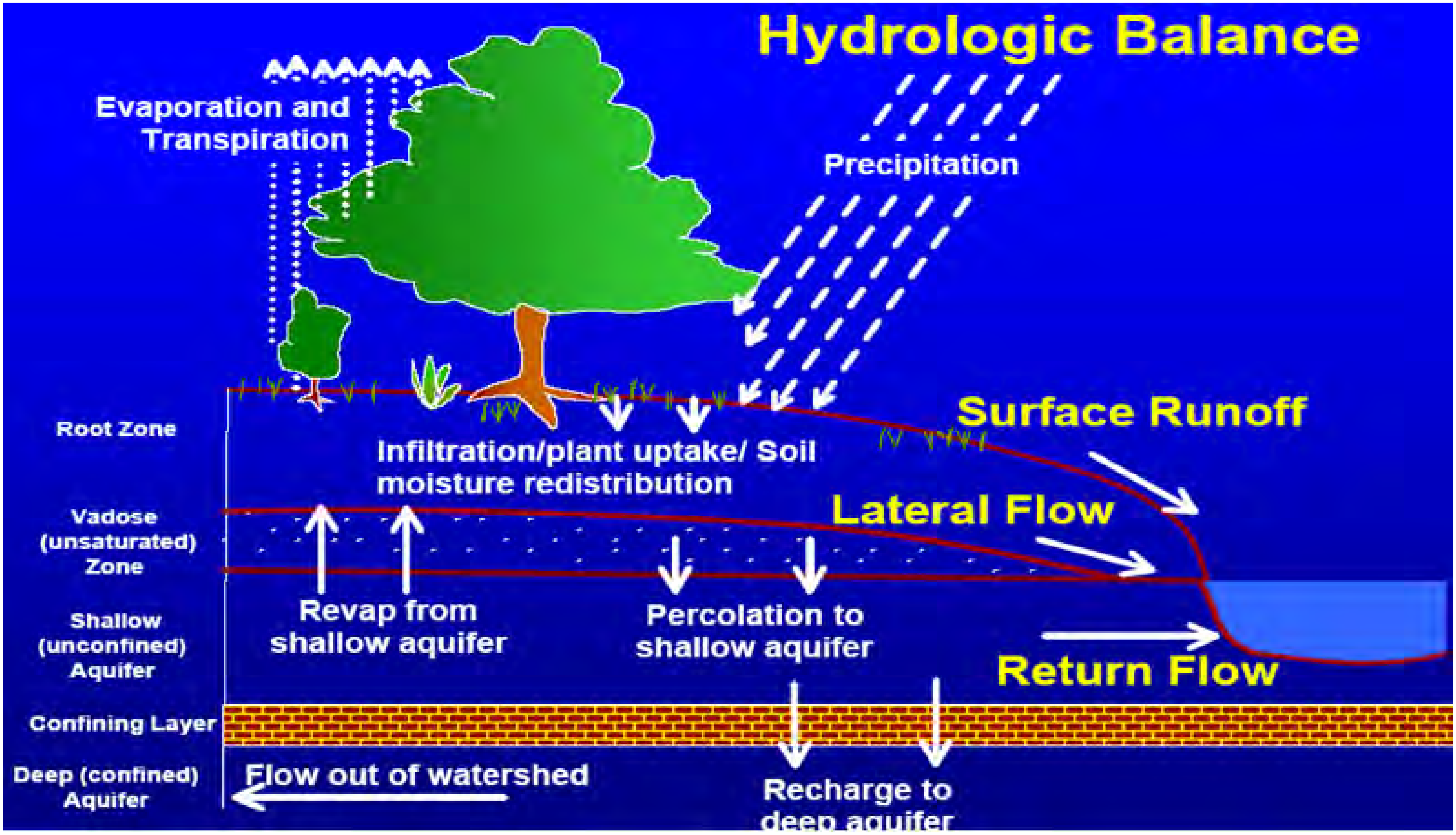


Study Area: Small Watersheds

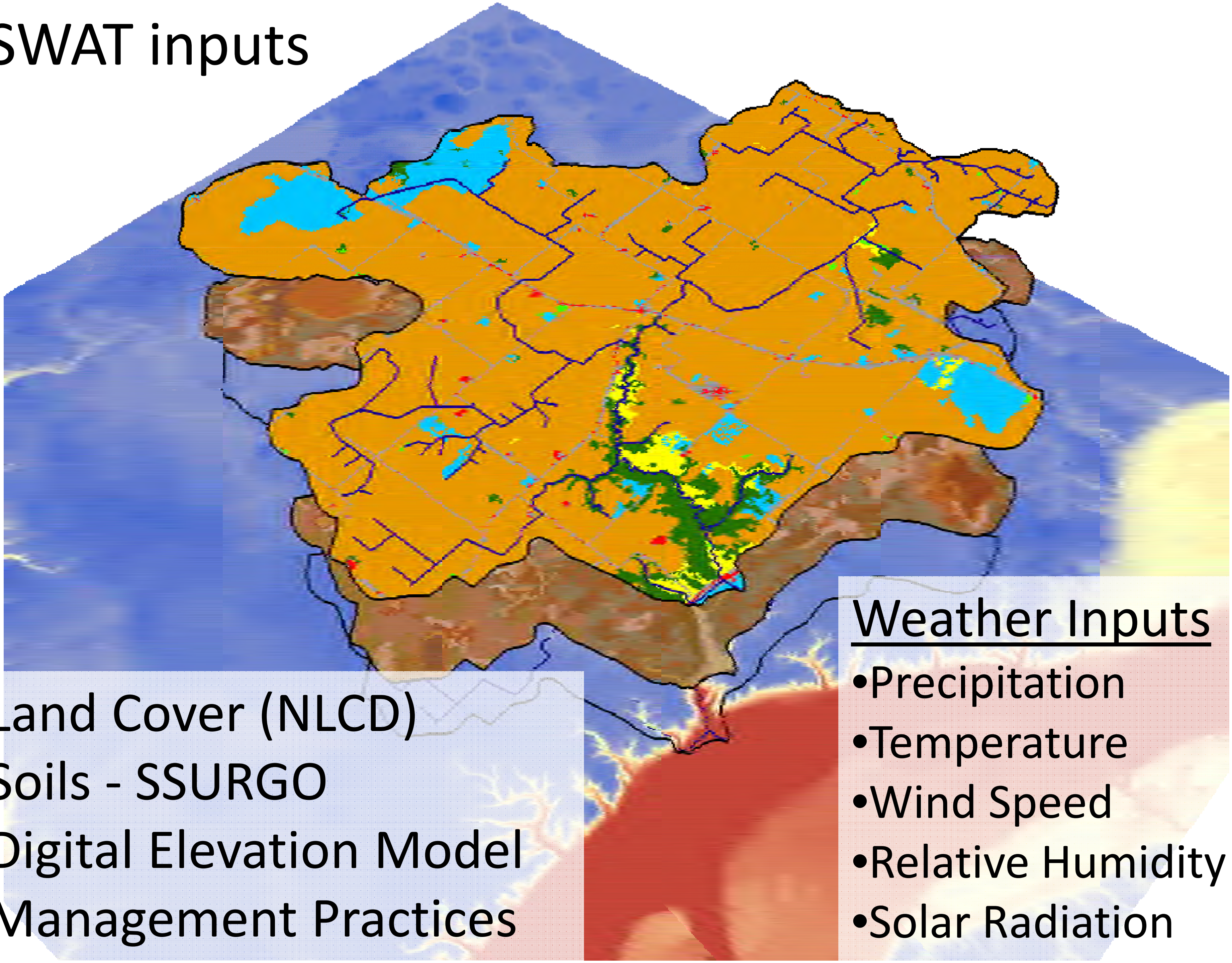
Important non-field sources of sediment at the upland/ravine interface.

Soil & Water Assessment Tool (SWAT)

Plant Growth, Hydrology, Erosion, Sediment and Nutrients export



SWAT inputs



Land Cover (NLCD)
Soils - SSURGO
Digital Elevation Model
Management Practices

Weather Inputs

- Precipitation
- Temperature
- Wind Speed
- Relative Humidity
- Solar Radiation

WOODS INSTITUTE FOR THE ENVIRONMENT STANFORD UNIVERSITY

WWF

The Nature Conservancy

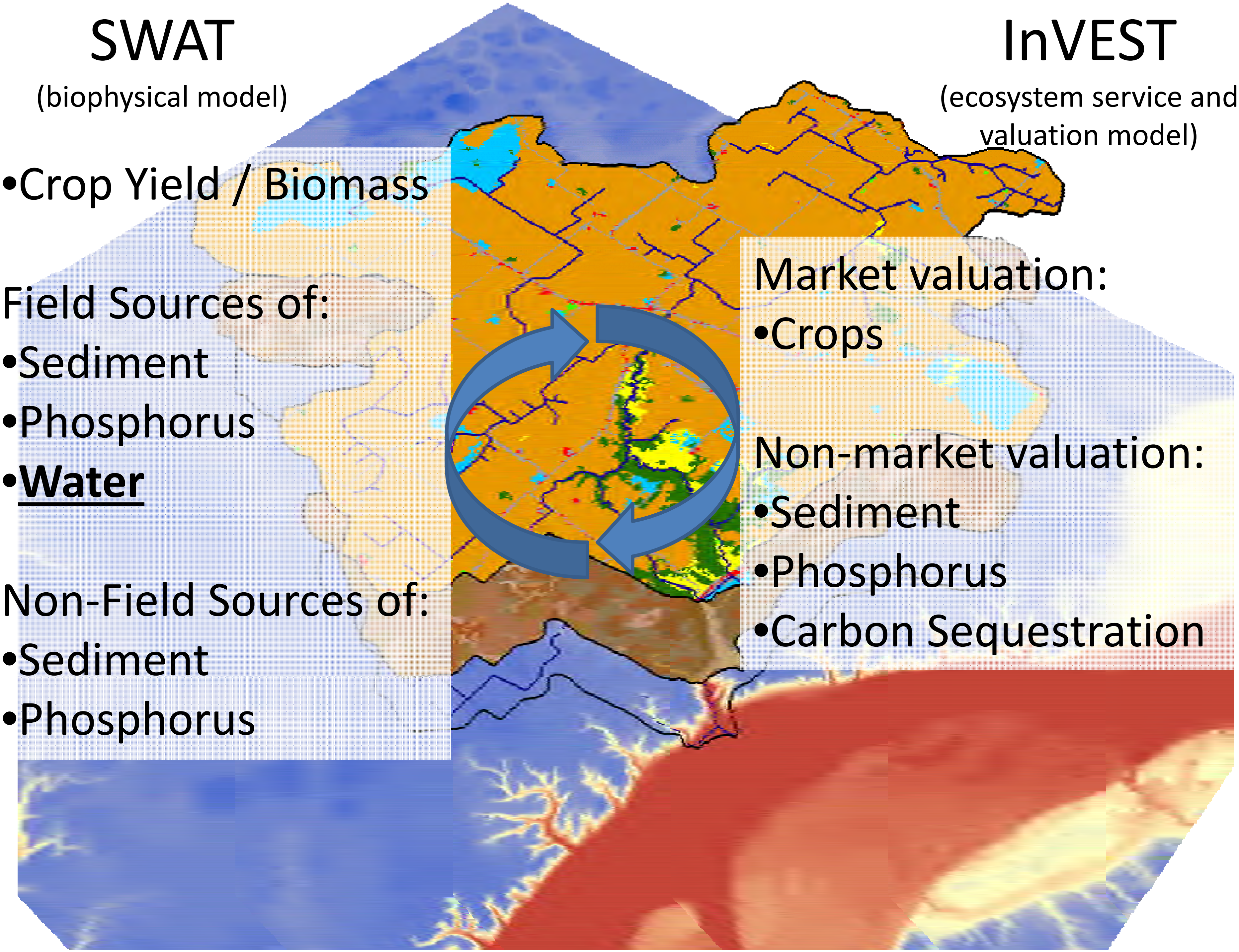
INSTITUTE ON THE ENVIRONMENT
UNIVERSITY OF MINNESOTA
Driven to Discover

natural capital PROJECT

ALIGNING ECONOMIC FORCES WITH CONSERVATION

“InVEST”
Integrated **V**aluation of **E**cosystem **S**ervices and **T**radeoffs

http://www.naturalcapitalproject.org/InVEST.html

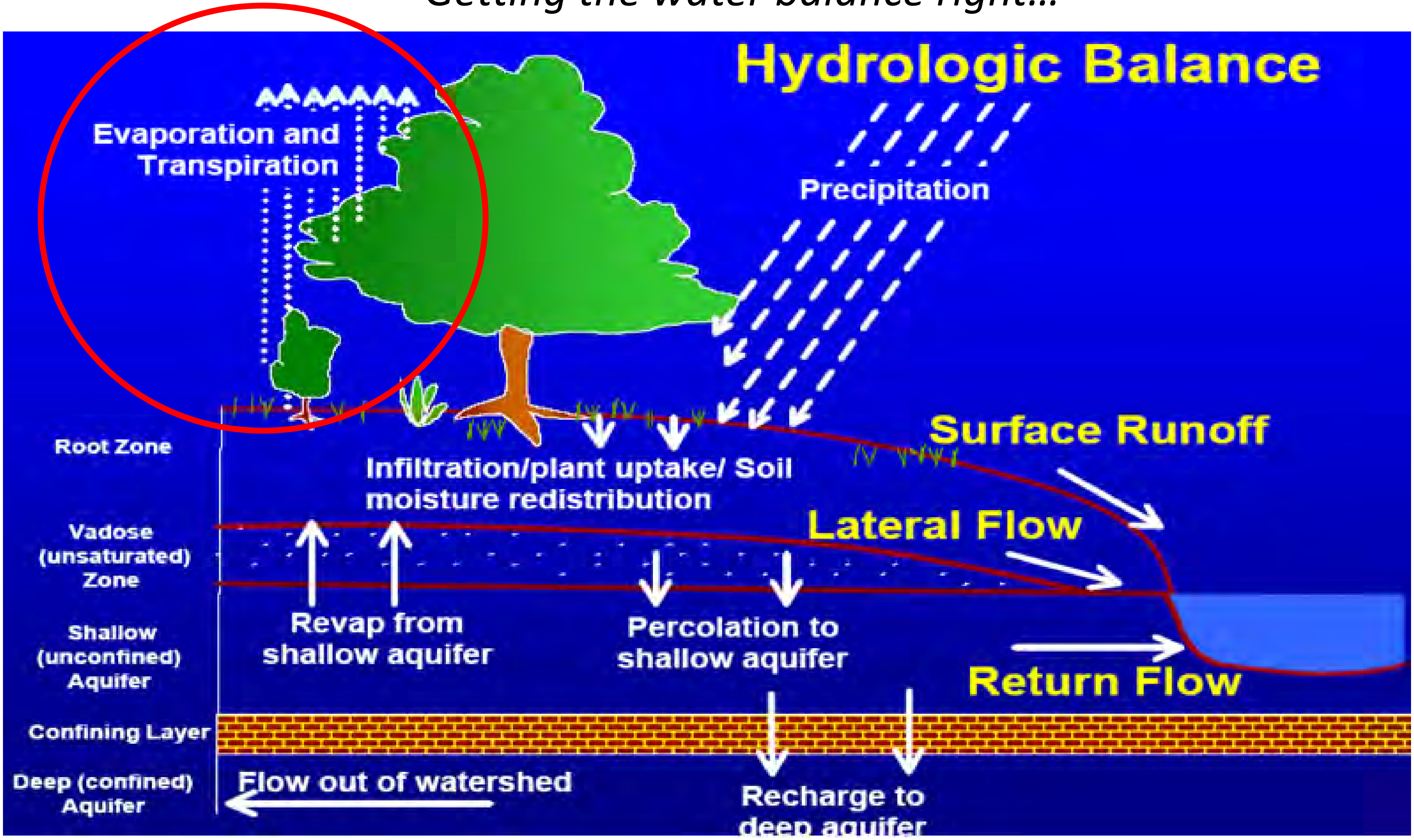

SWAT
(biophysical model)
•Crop Yield / Biomass
Field Sources of:
•Sediment
•Phosphorus
•**Water**
Non-Field Sources of:
•Sediment
•Phosphorus
InVEST
(ecosystem service and valuation model)
Market valuation:
•Crops
Non-market valuation:
•Sediment
•Phosphorus
•Carbon Sequestration

Alternative Scenarios and Landscape Options

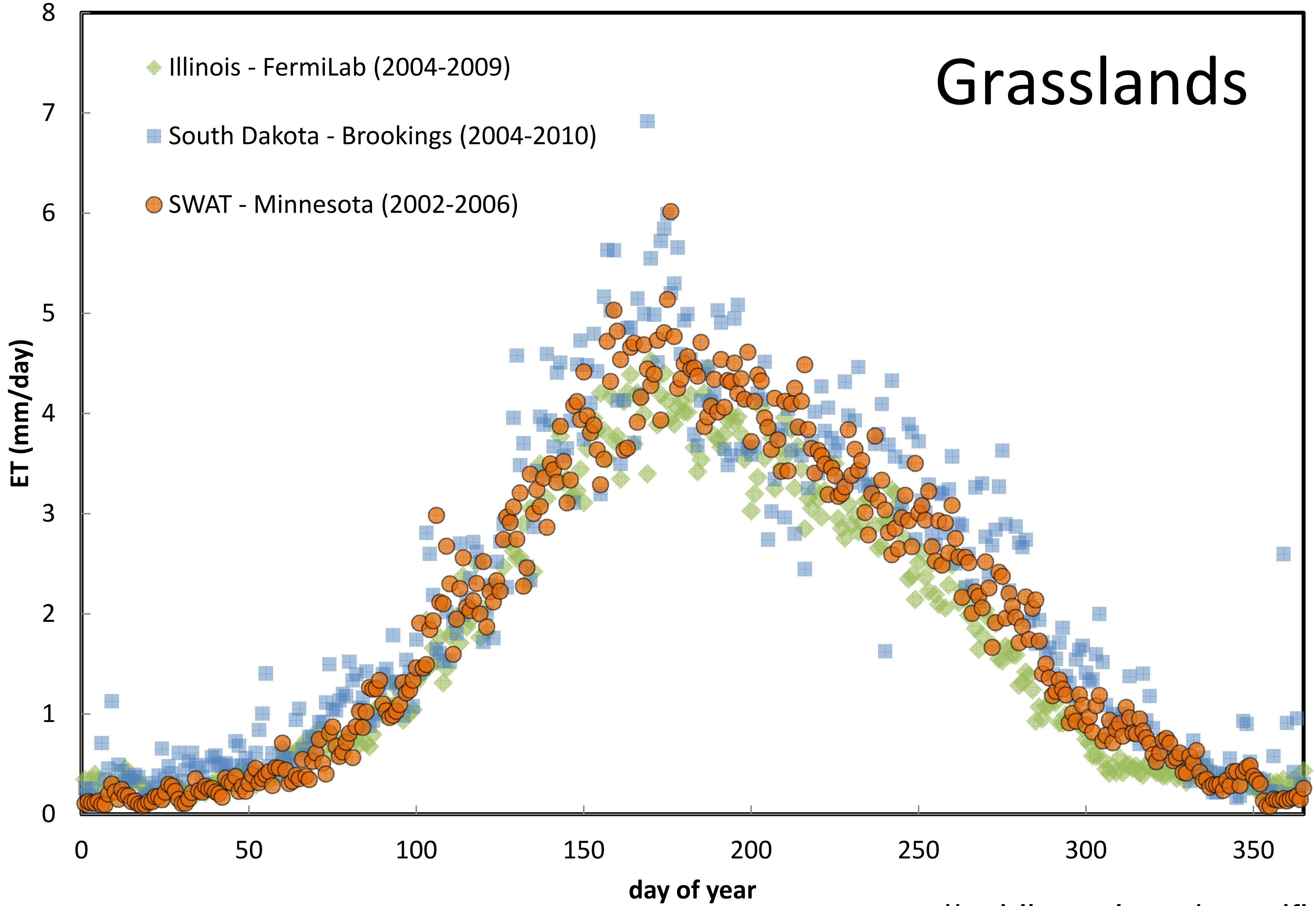
- **Conservation Tillage:** Chisel and disk tillage practices are replaced with a conservation tillage practice that leaves 30% residue at time of planting. Field cultivators are still used before planting.
- **Reduced P Fertilizer Application:** Fall application of P fertilizer is reduced by 50% from current levels. Manure application is unchanged.
- **Cropland Conversion to Grassland:** Biomass is harvested. Previous tile drainage systems remain intact.
- **Cropland Conversion to Switchgrass:** Biomass is harvested. Previous tile drainage systems remain intact.
- **Cropland Conversion to Forest:** Previous tile drainage systems remain intact.

Model calibration

Getting the water balance right…

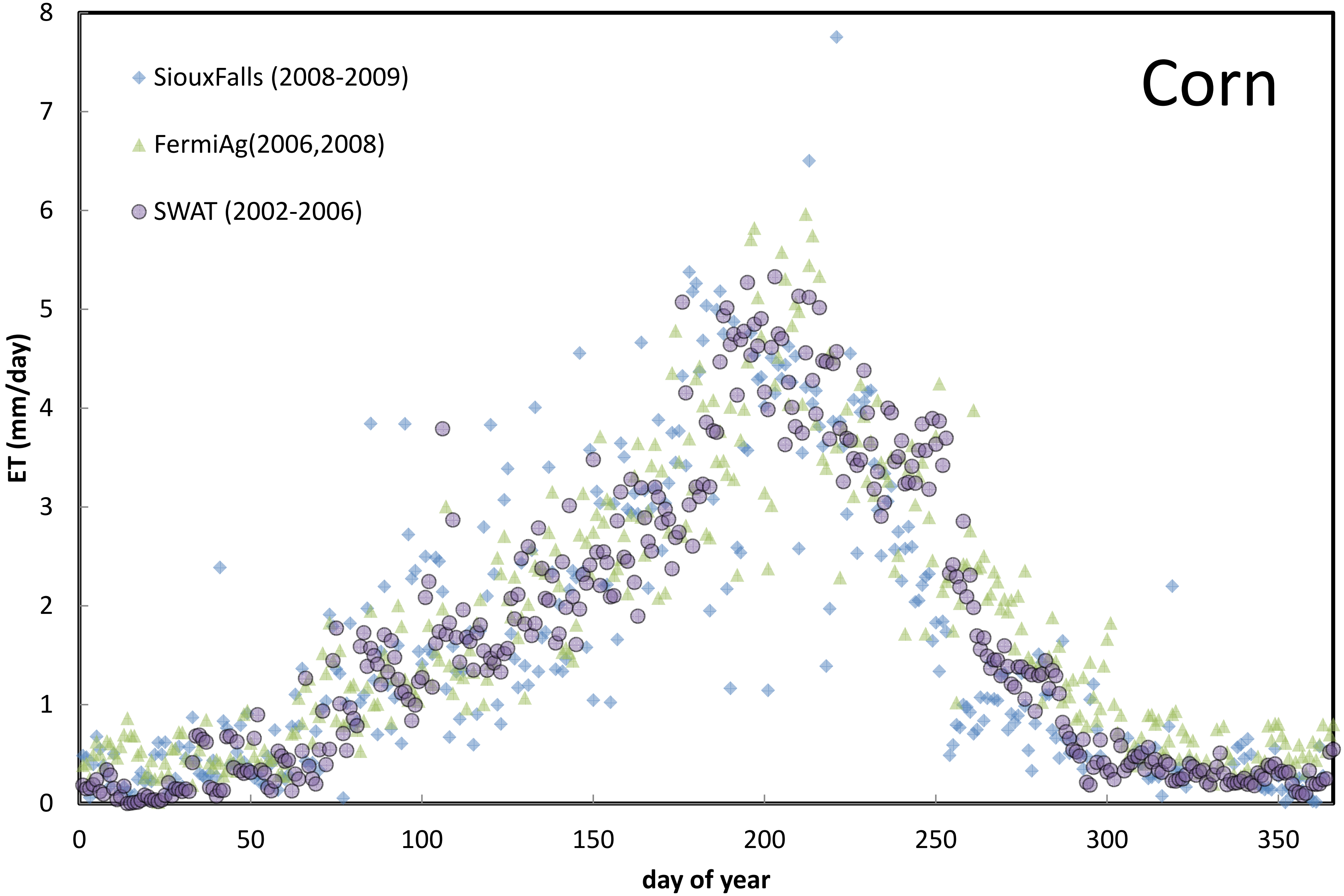


Getting the water balance right…



//public.ornl.gov/ameriflux

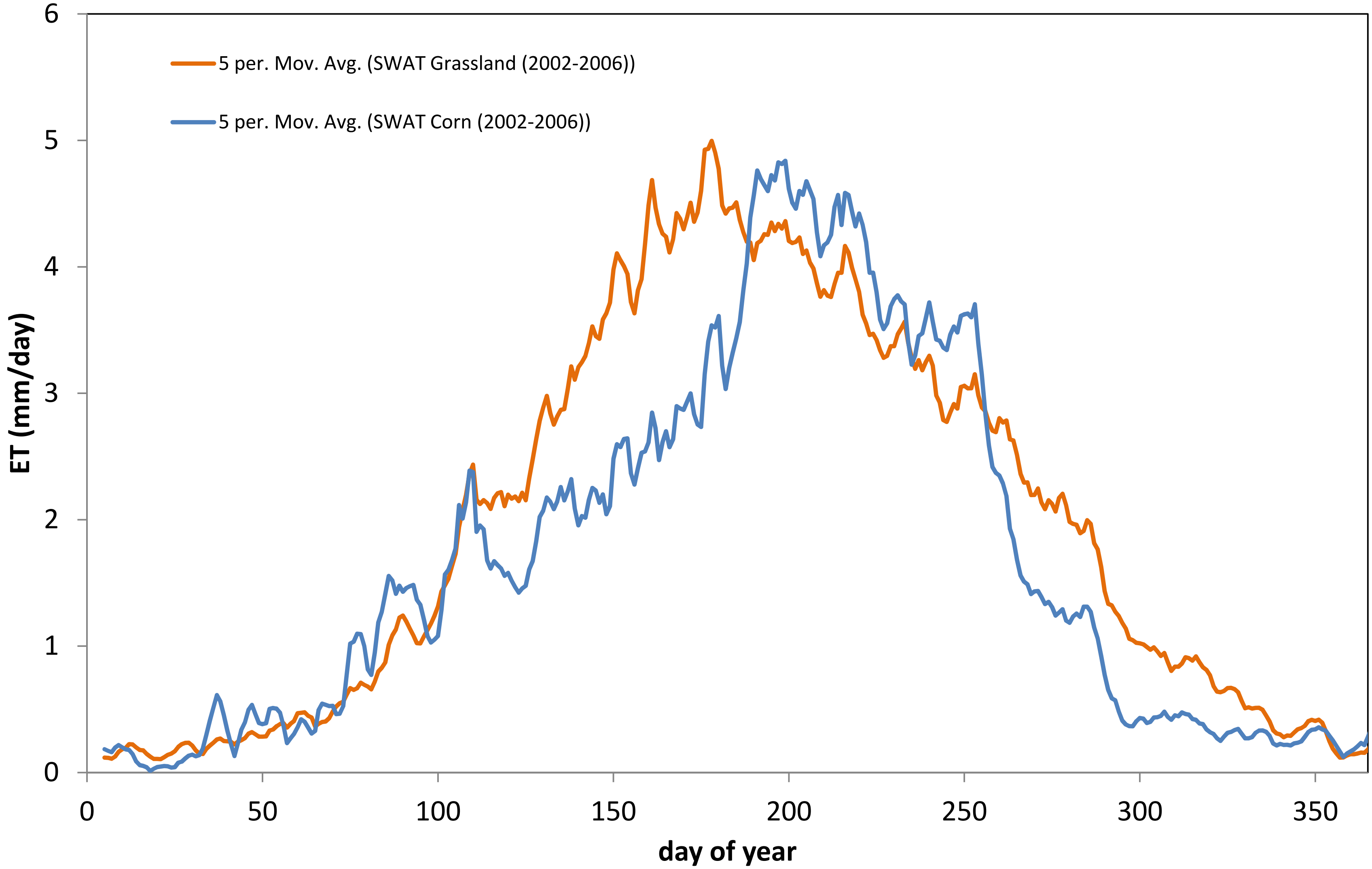
Getting the water balance right…



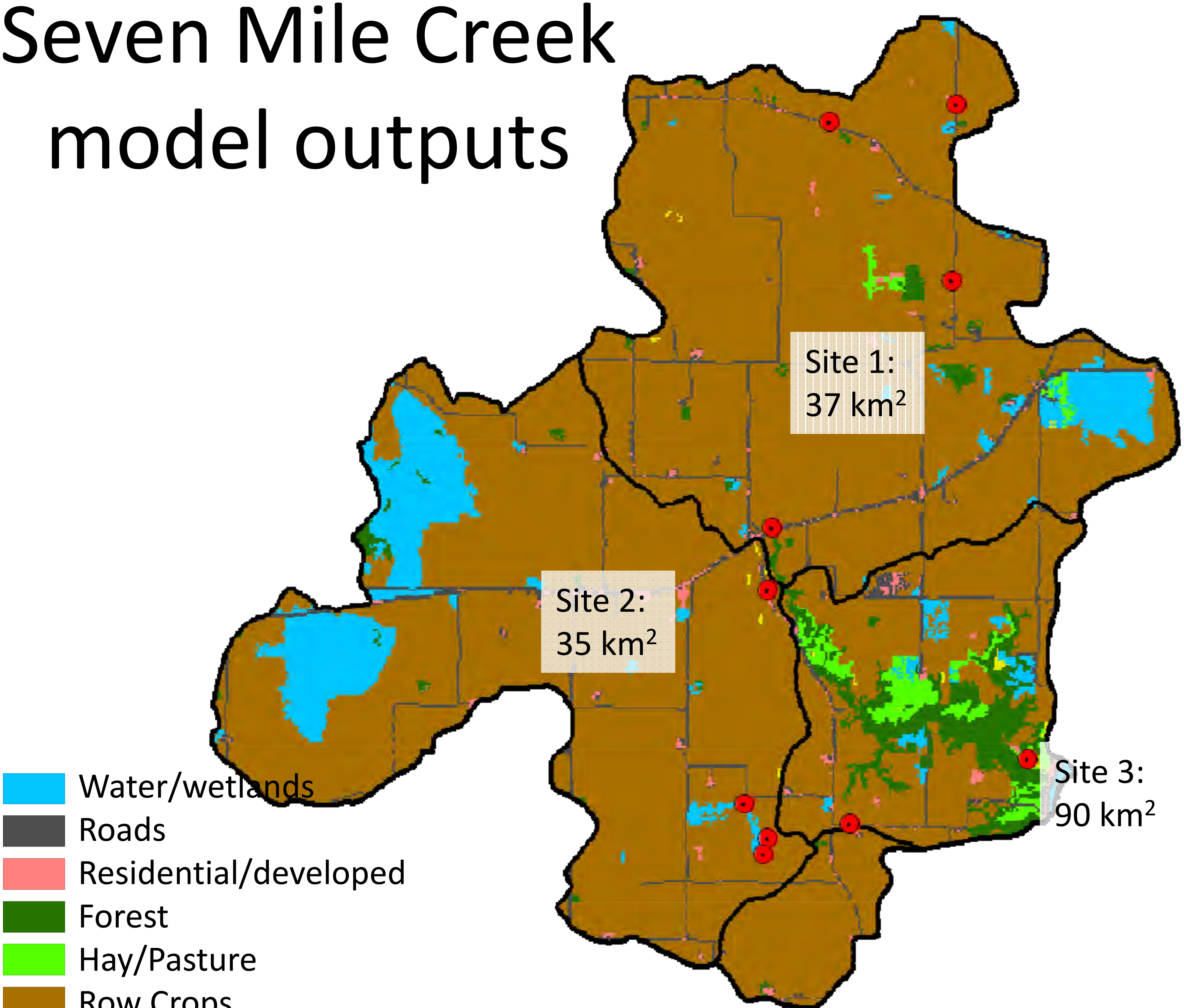
//public.ornl.gov/ameriflux

Grasslands-Corn ET comparison

Data from SWAT output

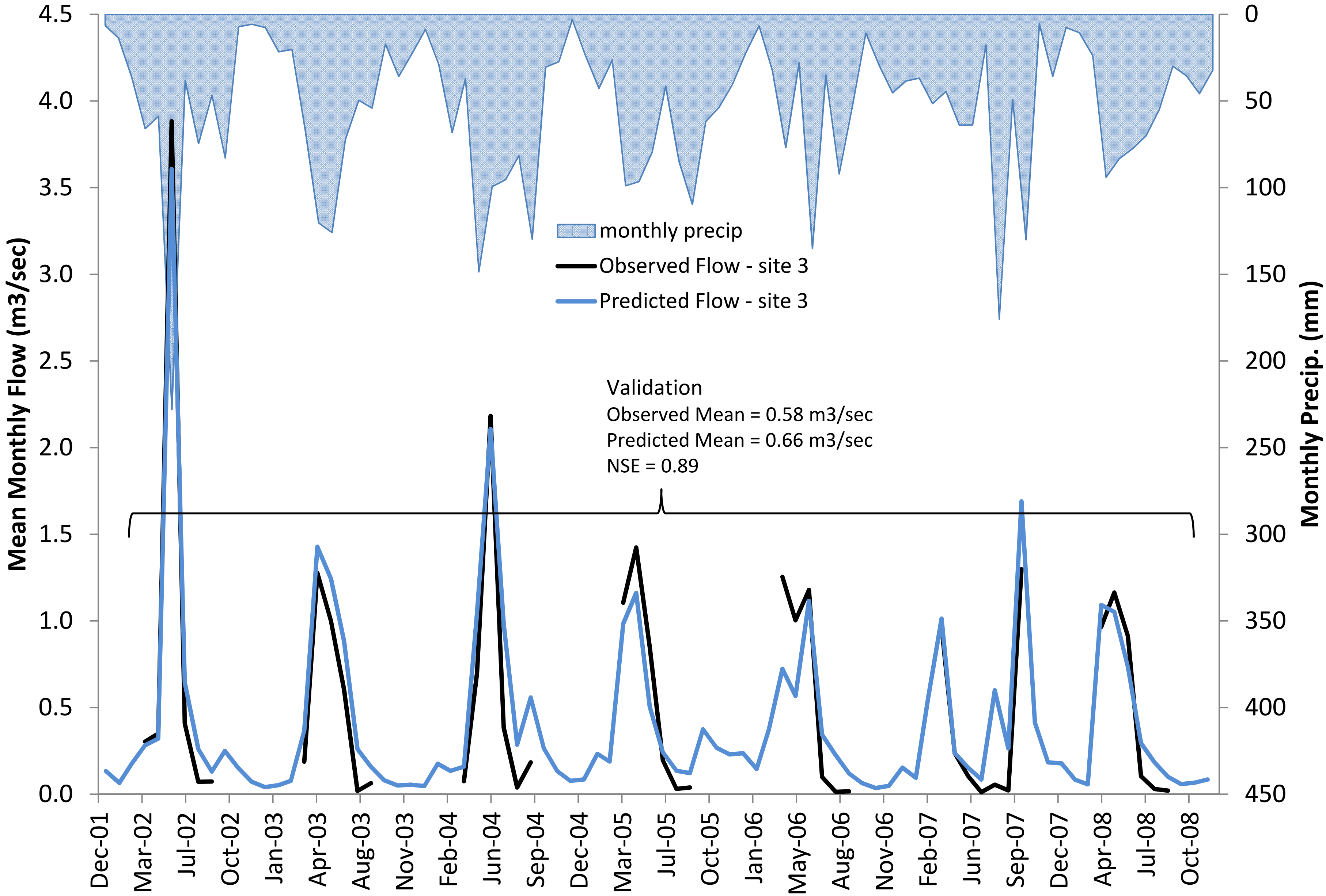


Seven Mile Creek model outputs

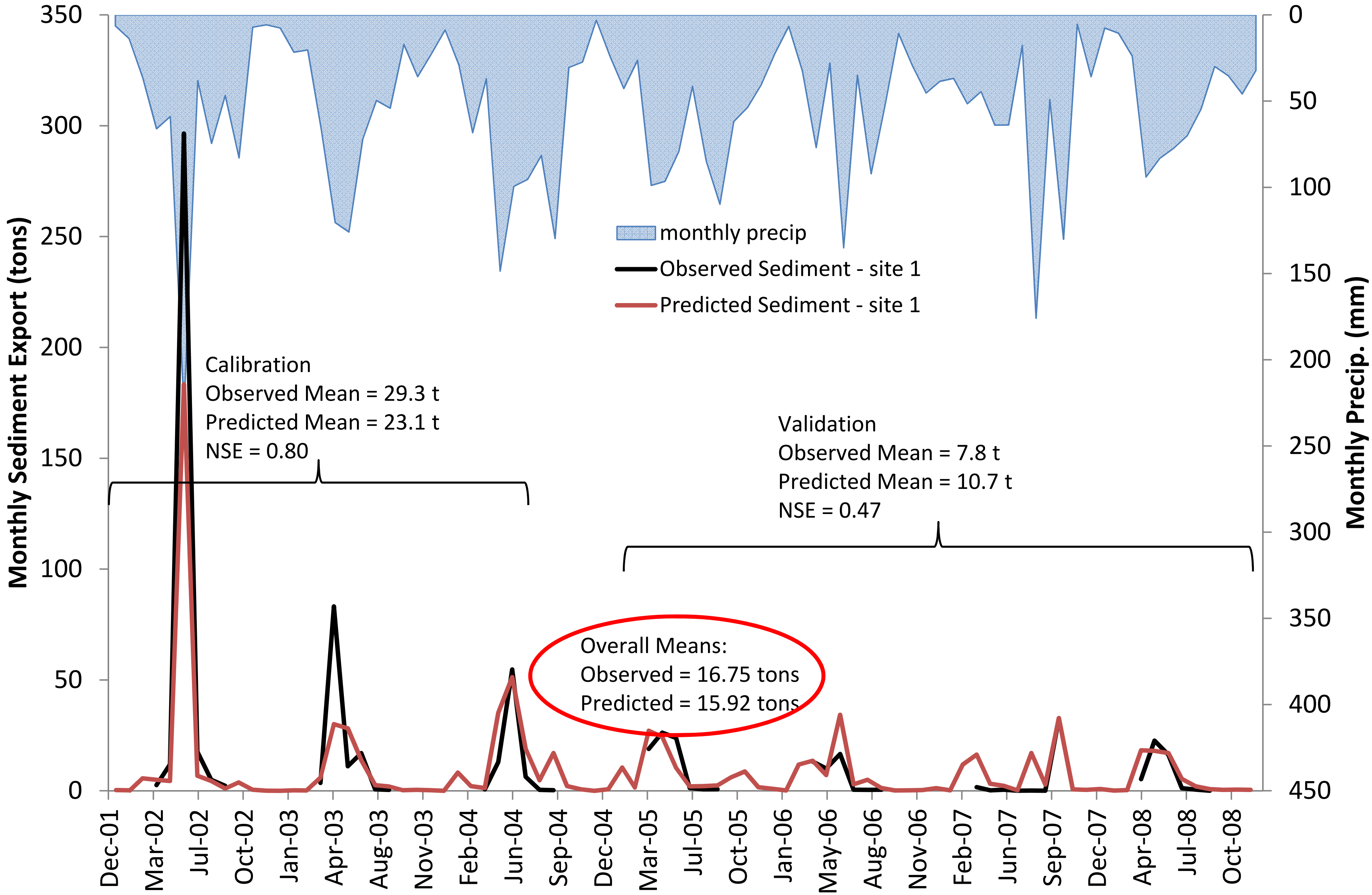


NLCD 2001

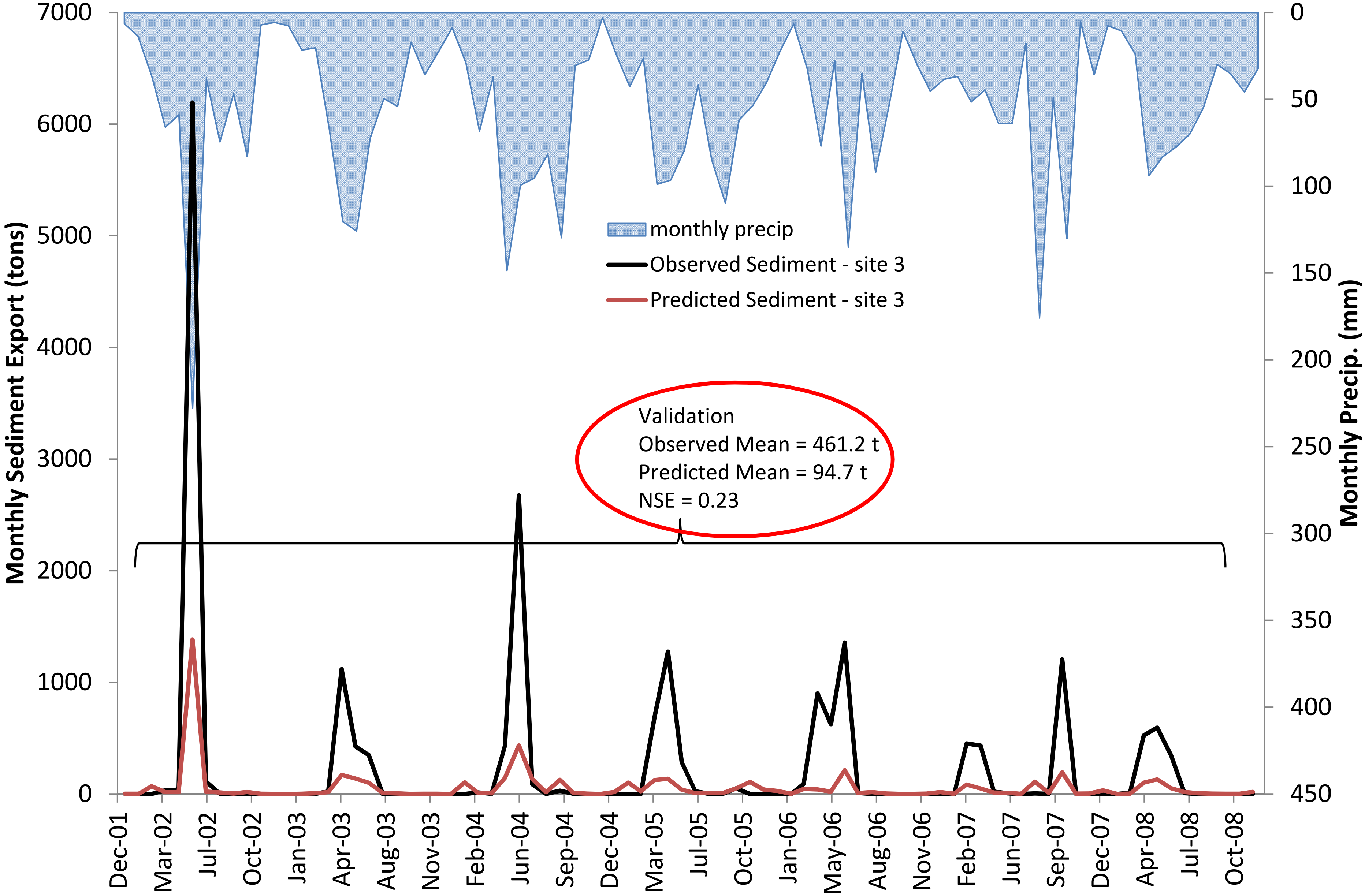
Flow – watershed outlet



Sediment – upland site 1

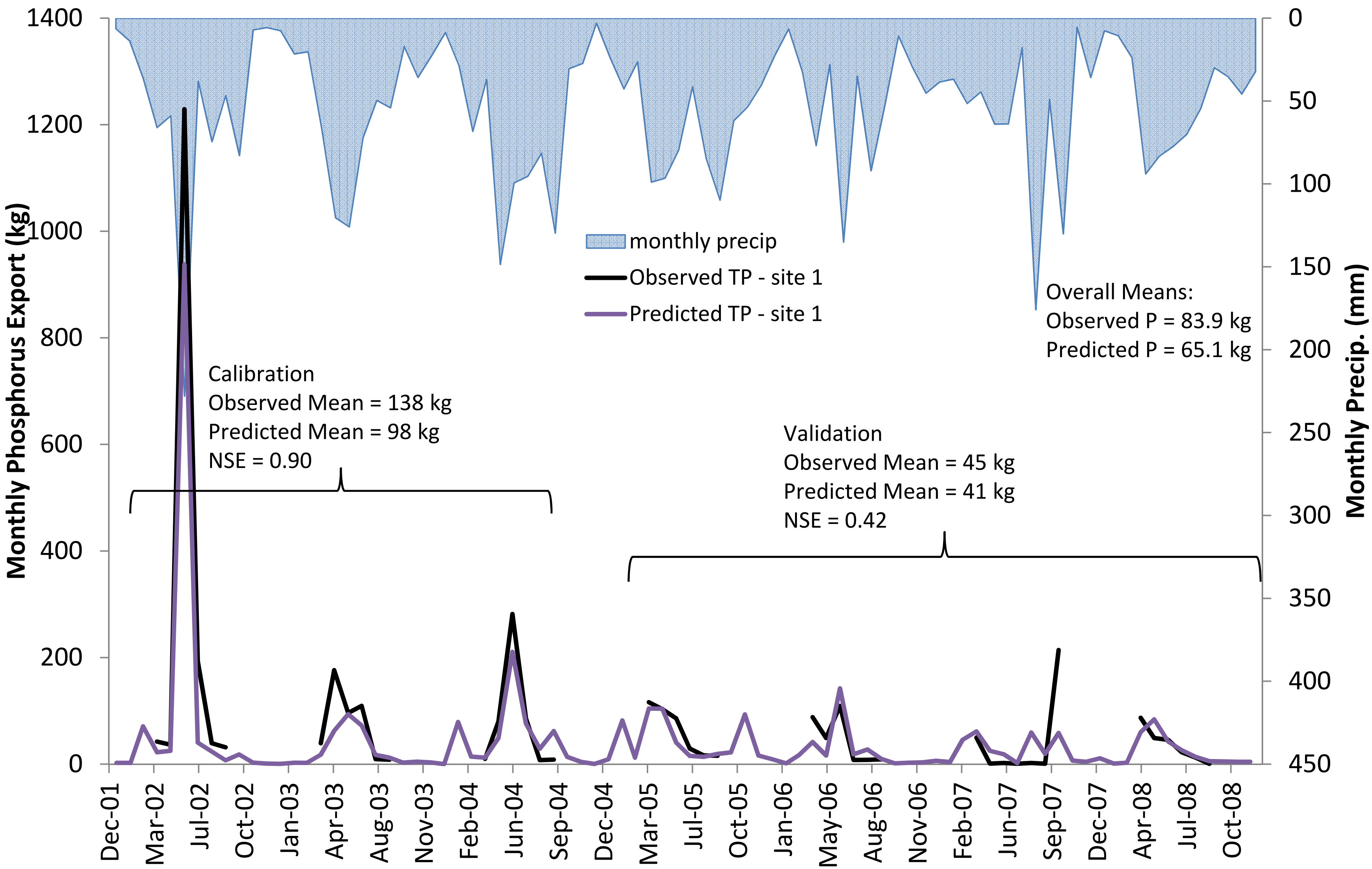


Sediment – watershed outlet

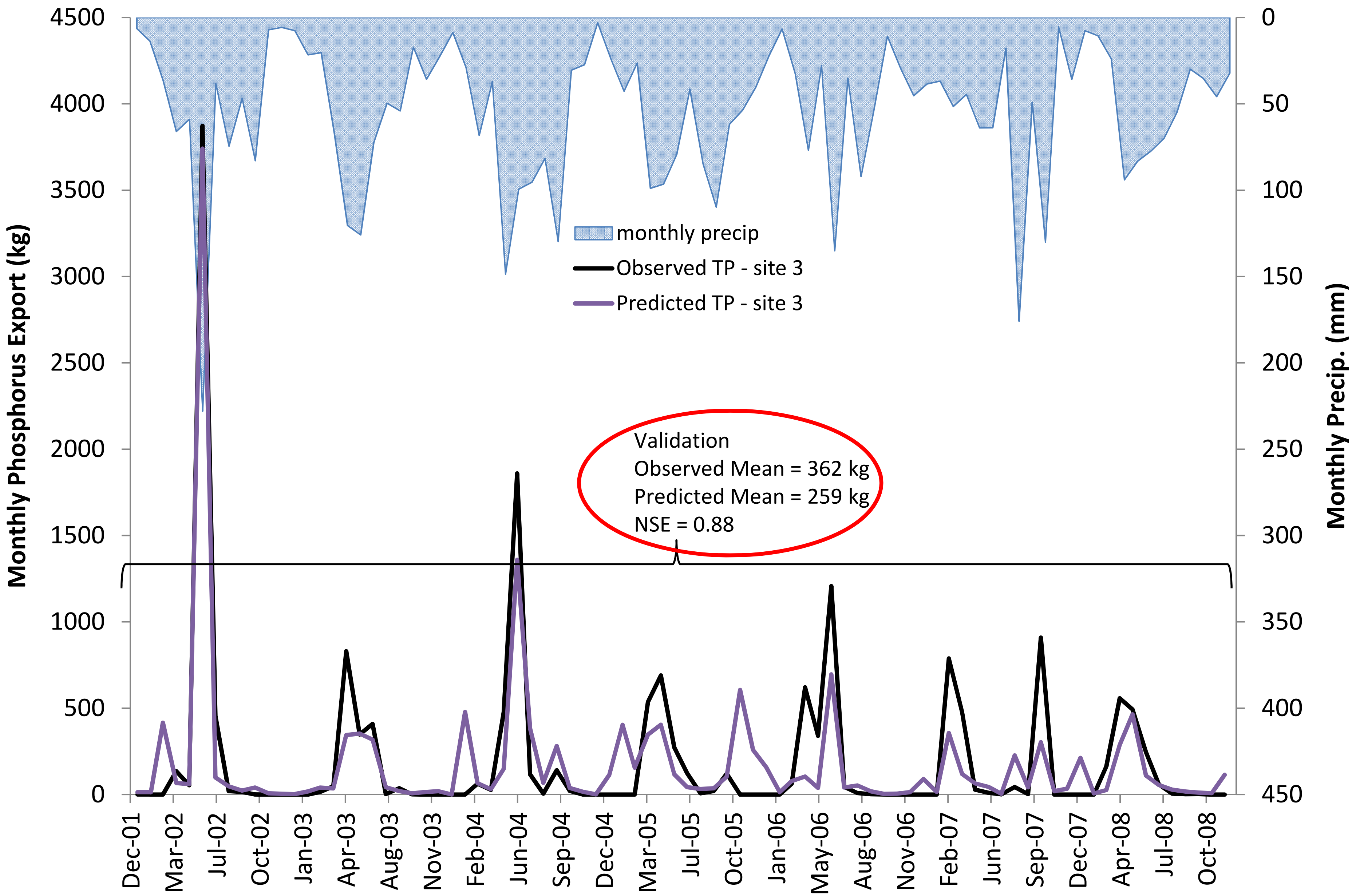


Important non-field sources of sediment at the upland/ravine interface.

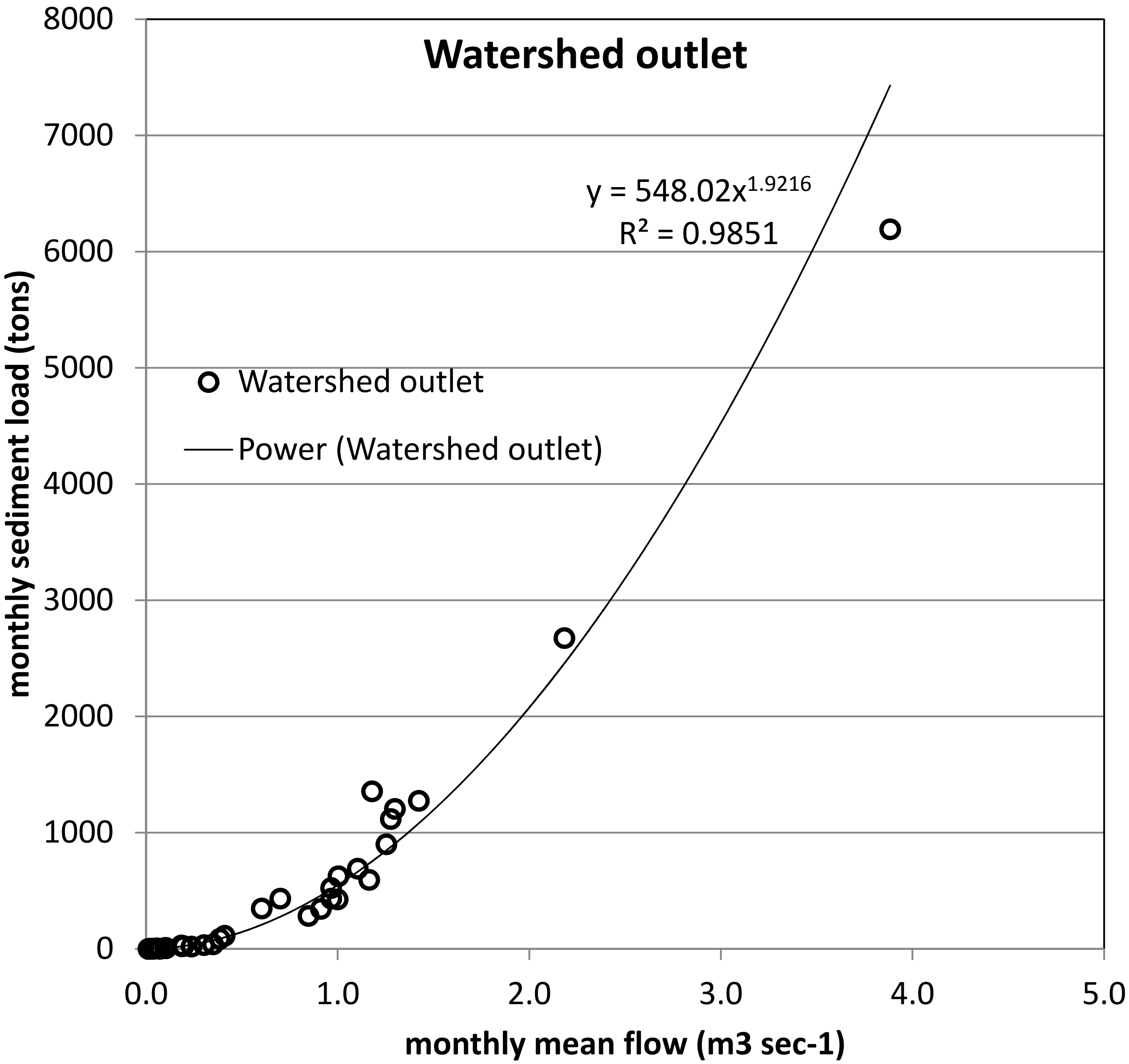
Phosphorus – upland site 1



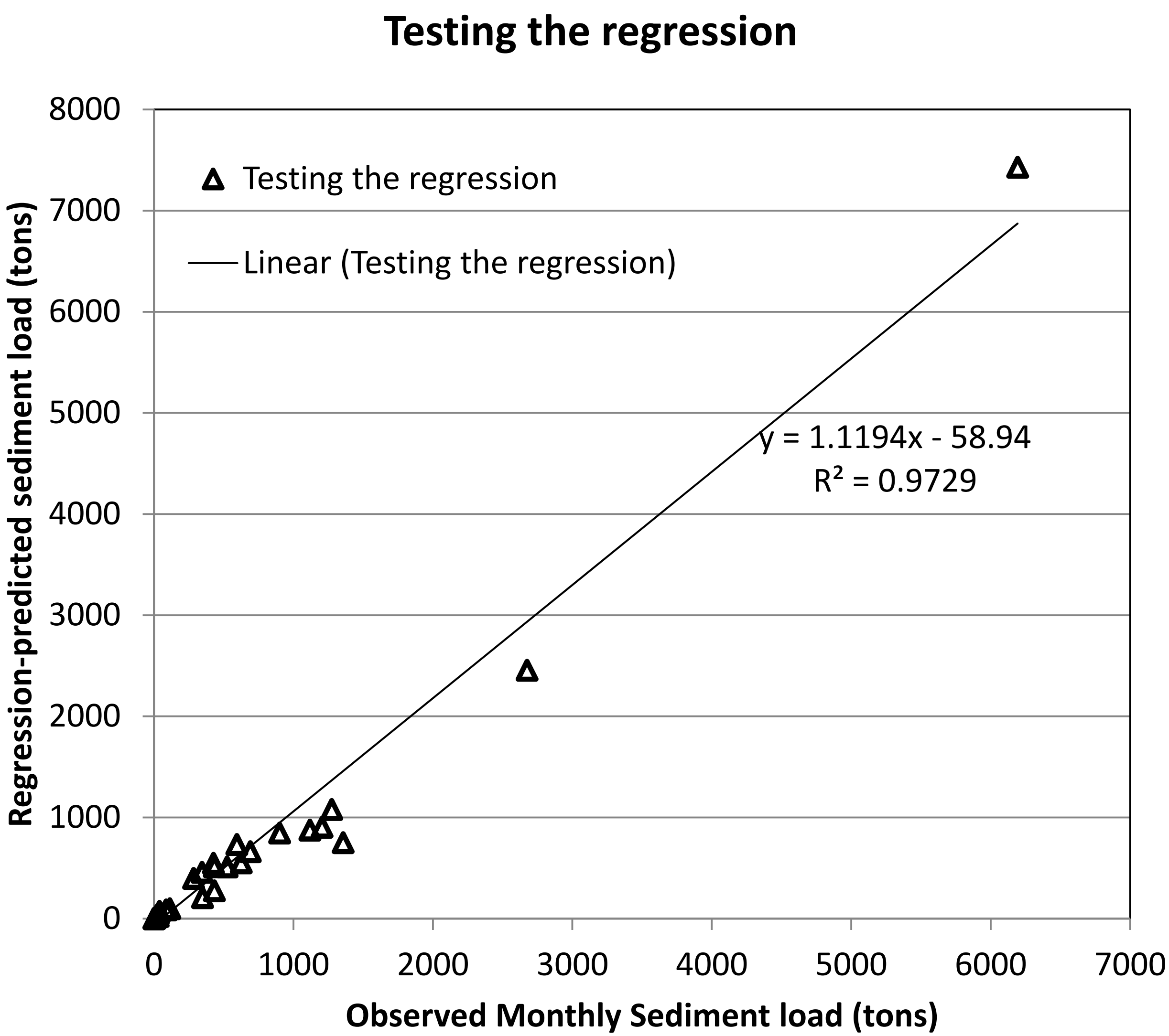
Phosphorus – watershed outlet



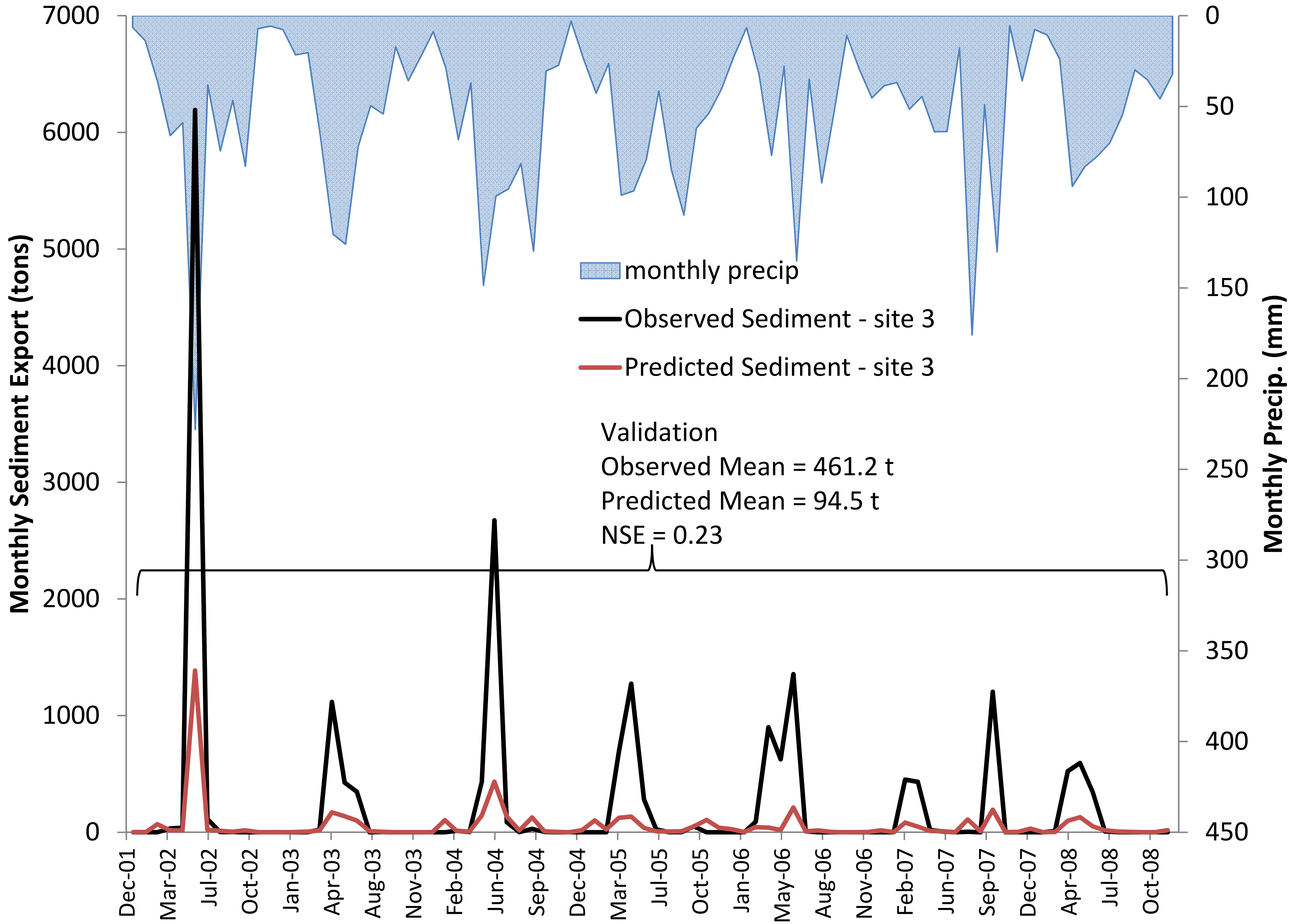
Flow-Sediment relationship at watershed outlet



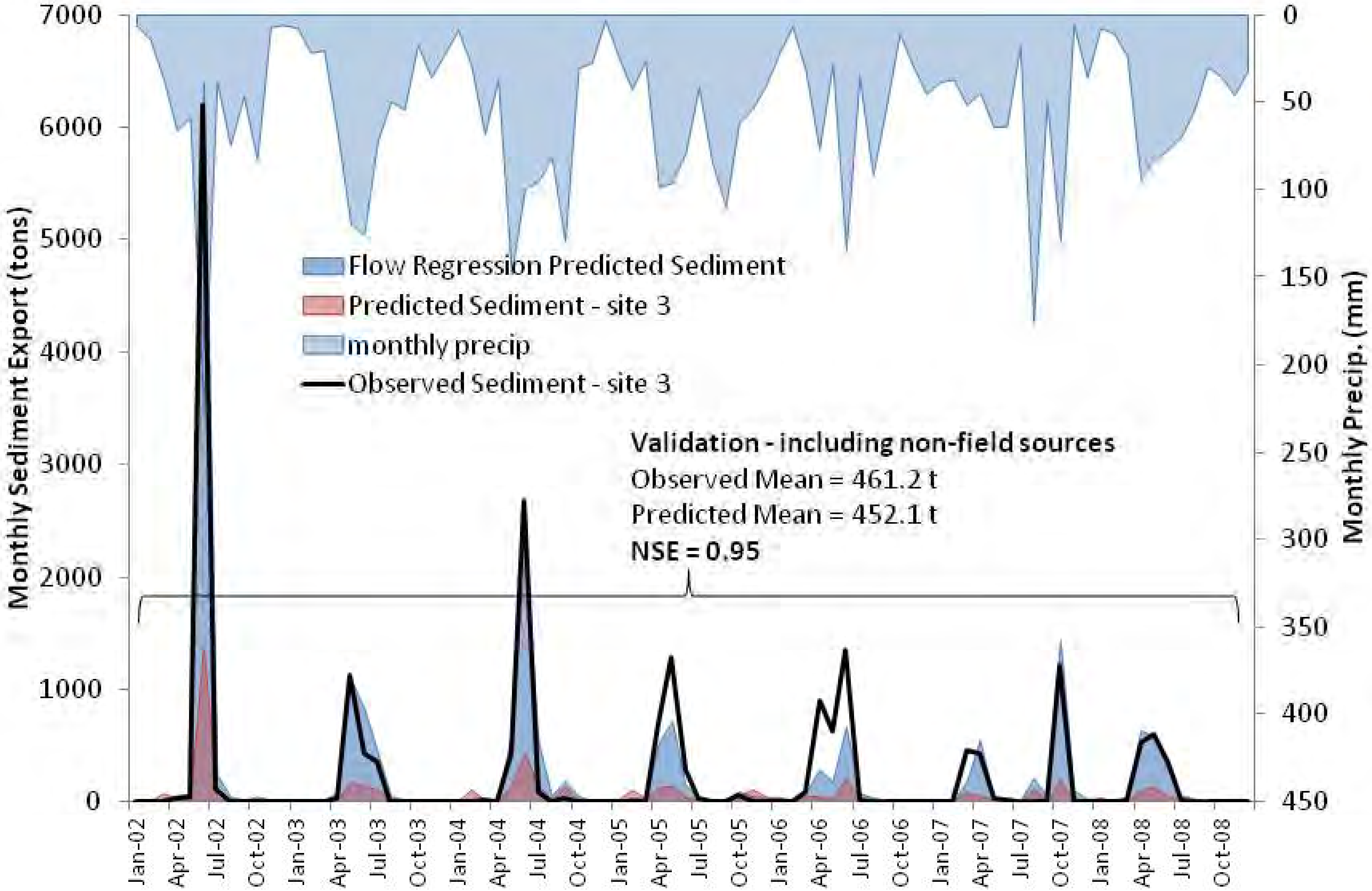
Comparison of observed and regression-predicted monthly sediment loads.



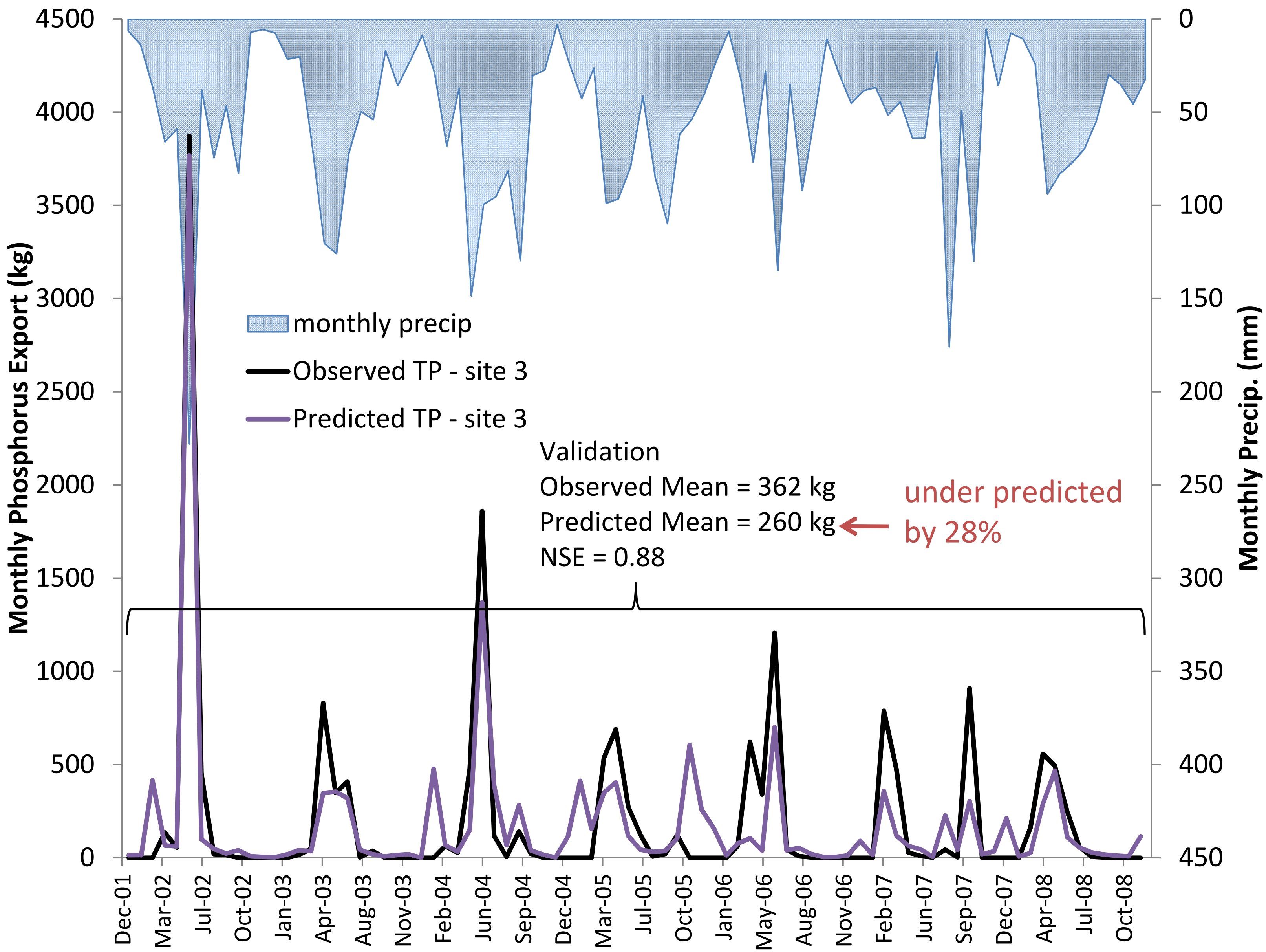
SWAT-predicted sediment from field sources



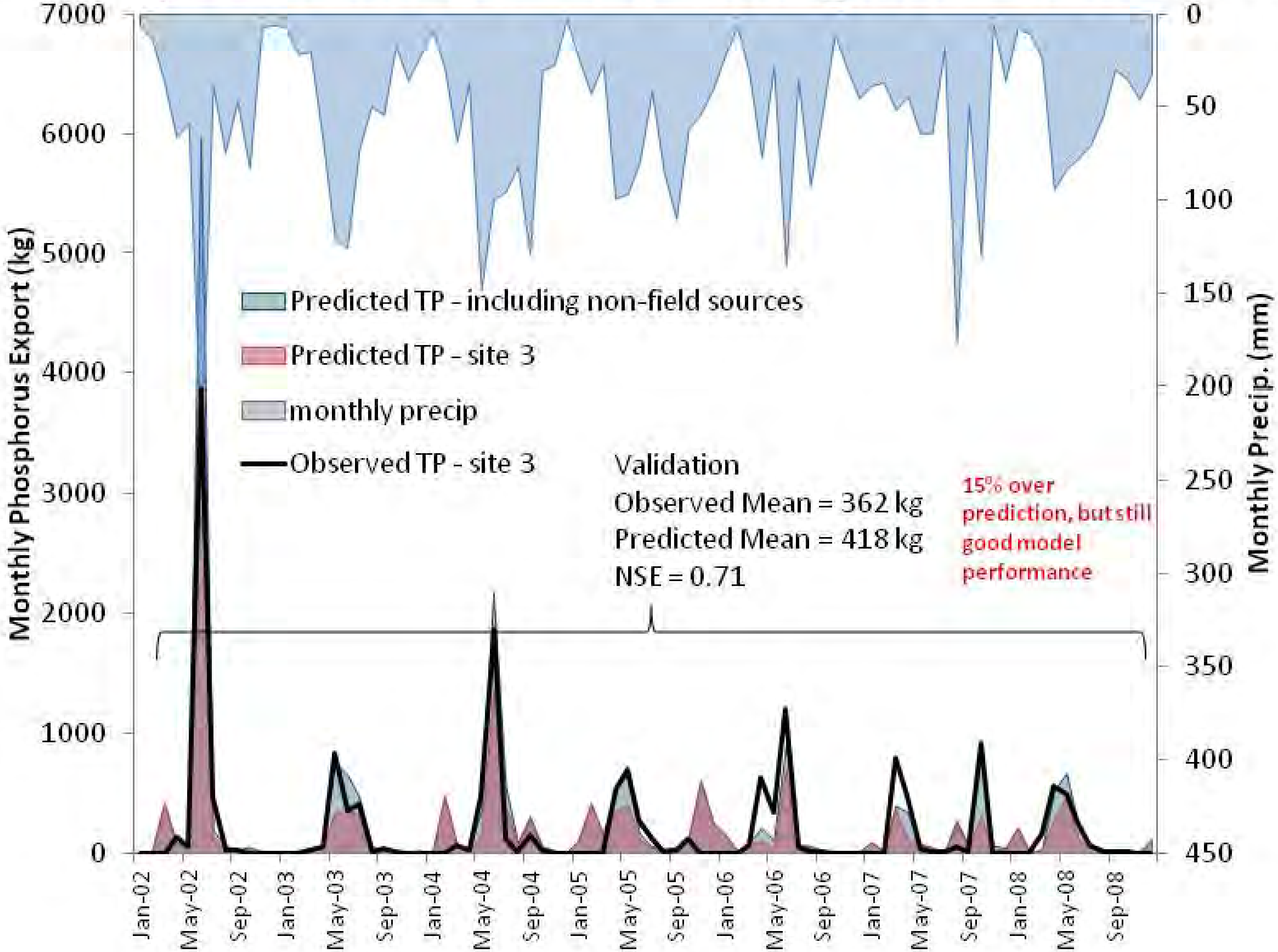
Model performance – including non-field sources



SWAT-predicted phosphorus from field sources

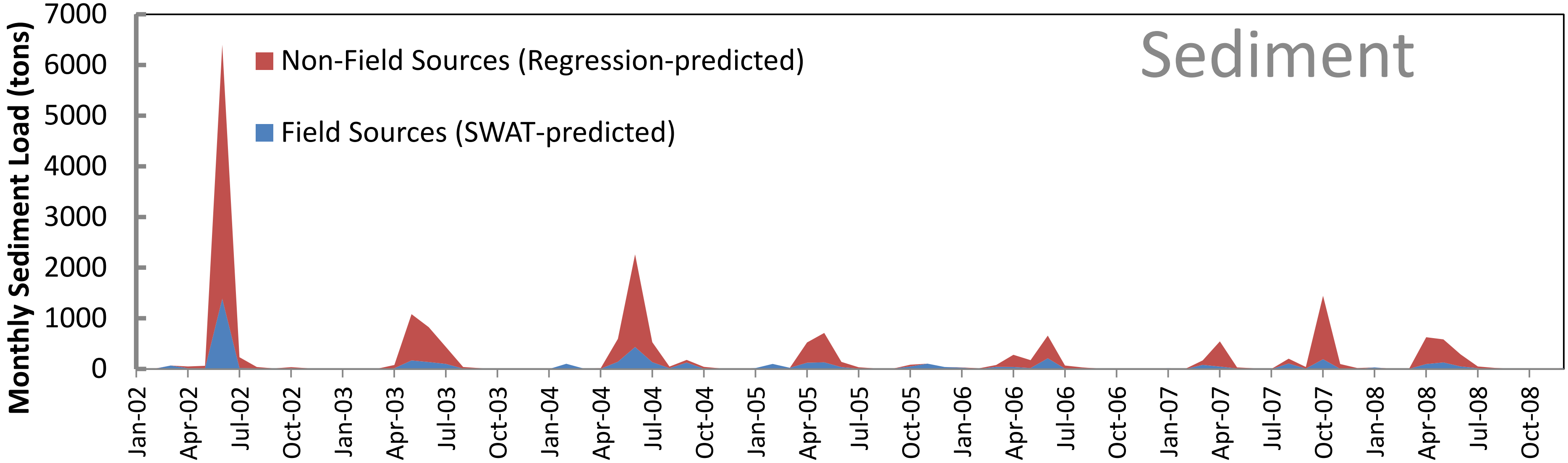


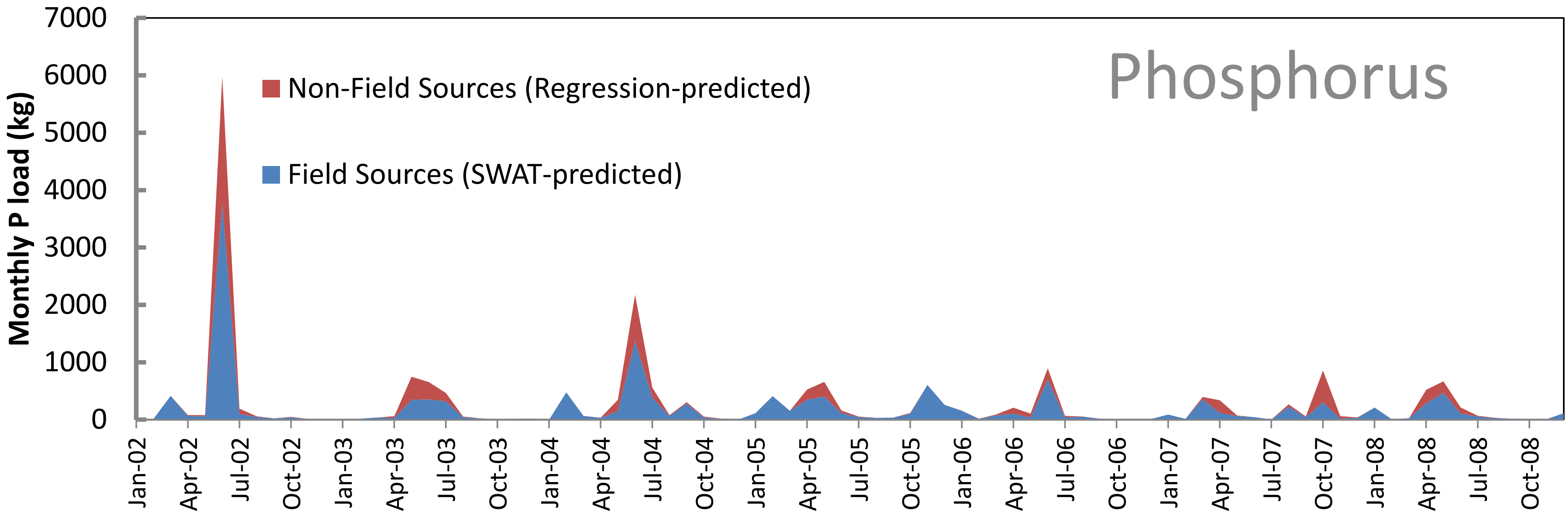
Model performance – including non-field sources



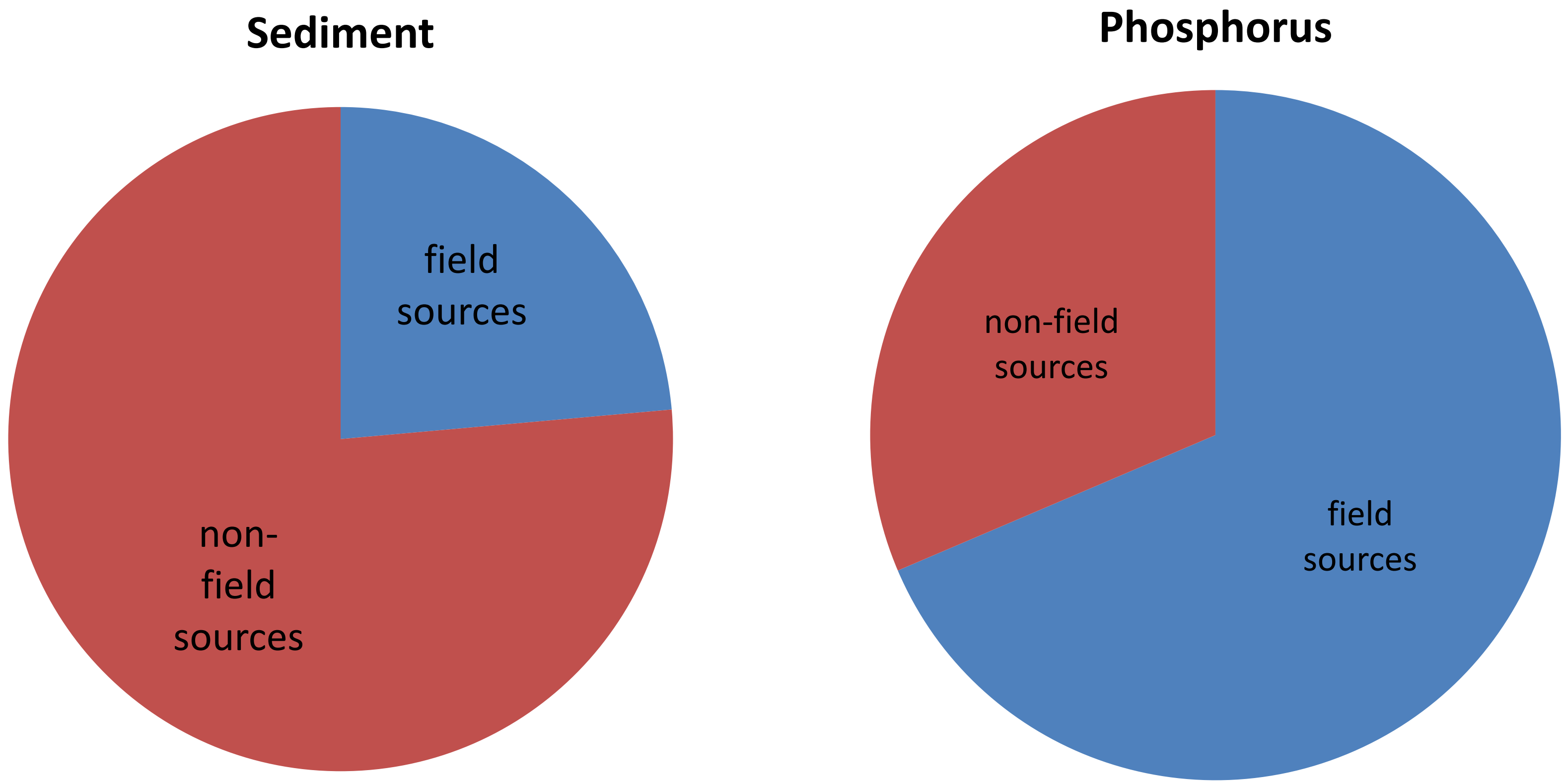
Assumes P content of streambank sediment is 441ppm after Sekely et al,. (2002)

Summary of sediment and phosphorus sources

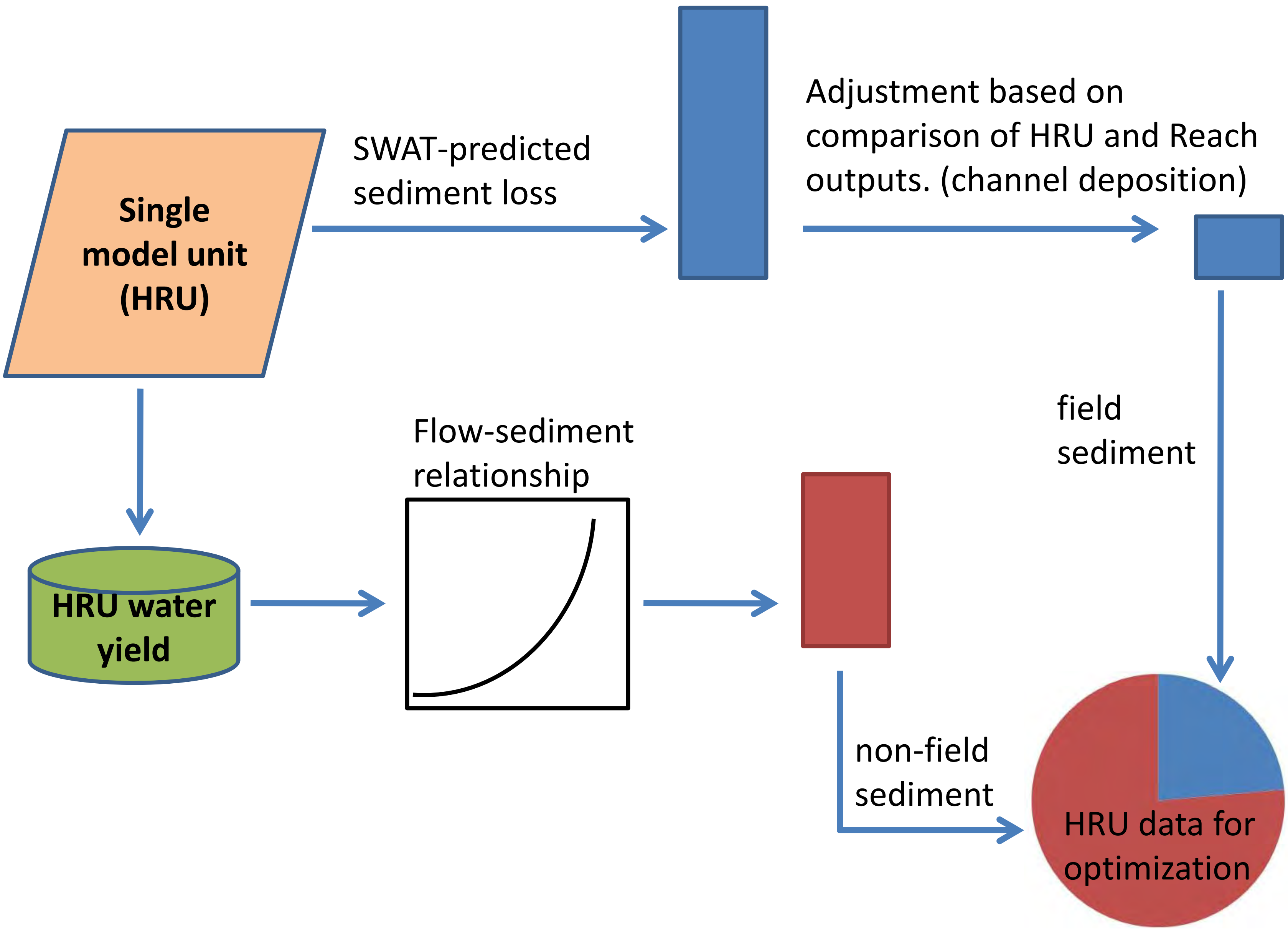




Average distribution of sediment and phosphorus sources

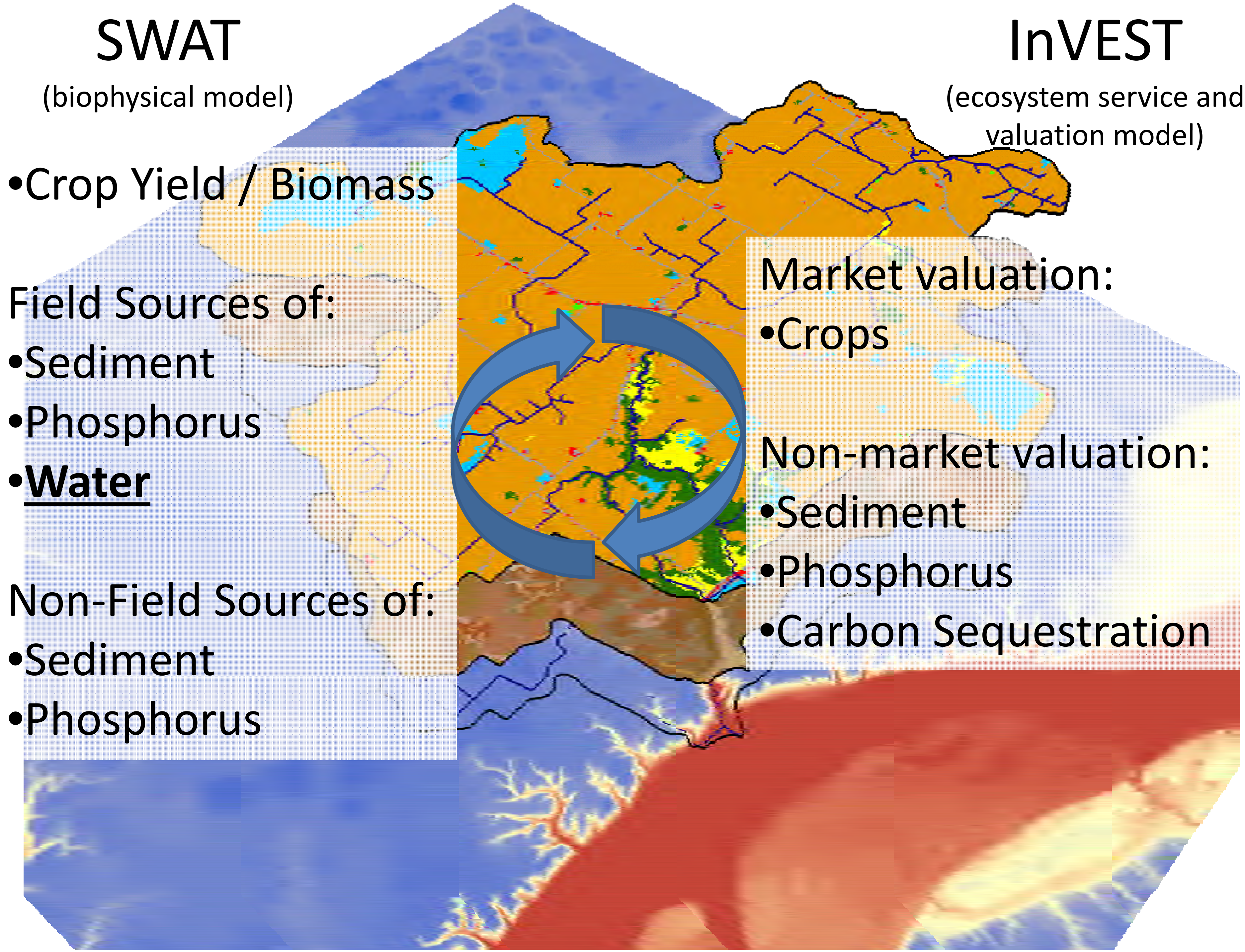


Data preparation schematic for optimization input



Optimization Methods

The quest for the Efficiency Frontier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(biophysical model)
•Crop Yield / Biomass
Field Sources of:
•Sediment
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•Water
Non-Field Sources of:
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InVEST
(ecosystem service and valuation model)
Market valuation:
•Crops
Non-market valuation:
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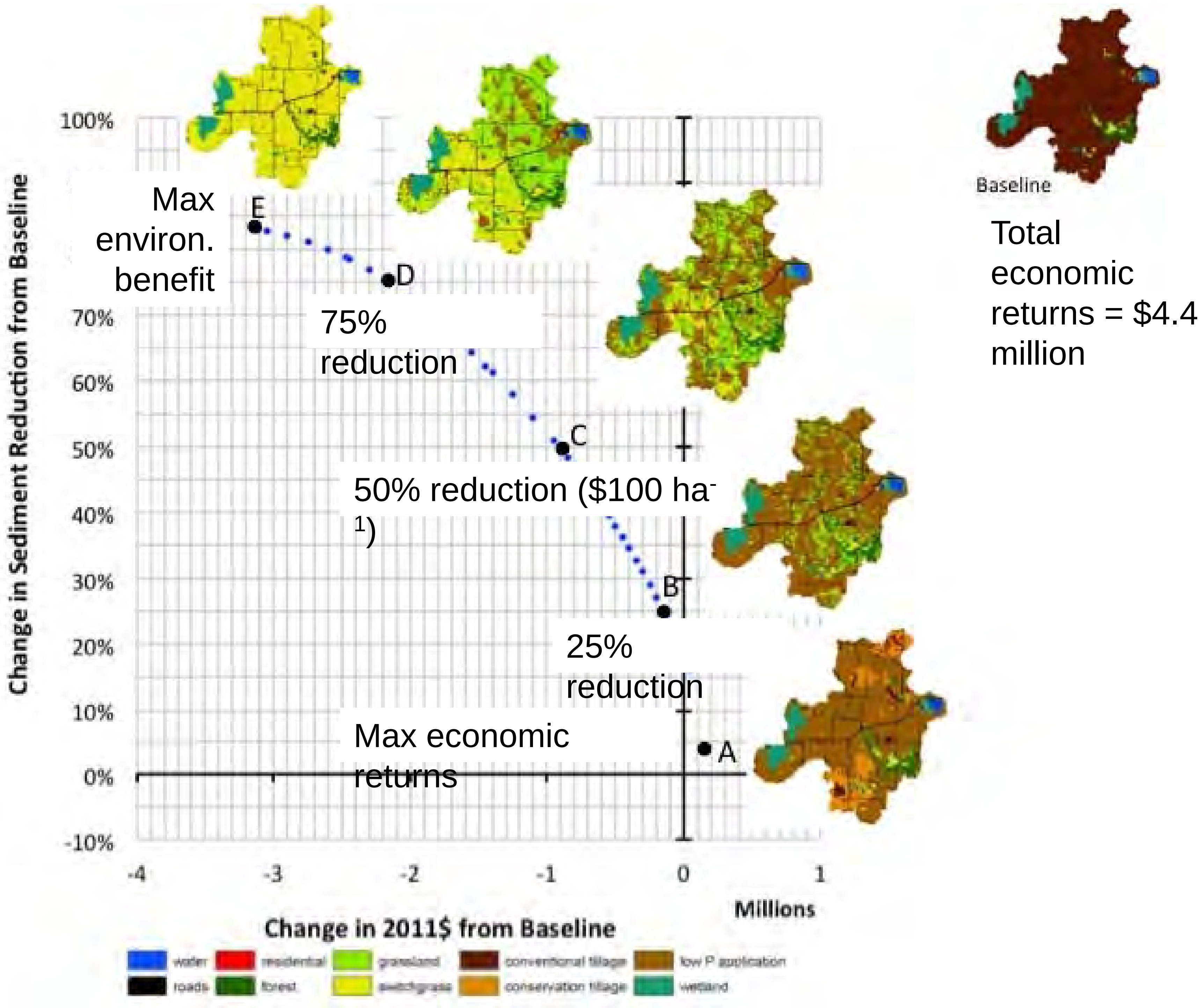
•Carbon Sequestration

Optimization Methods

- The goal of the analysis is to find land-use patterns that maximize the watershed TMDL reductions for a given watershed economic return, and vice versa

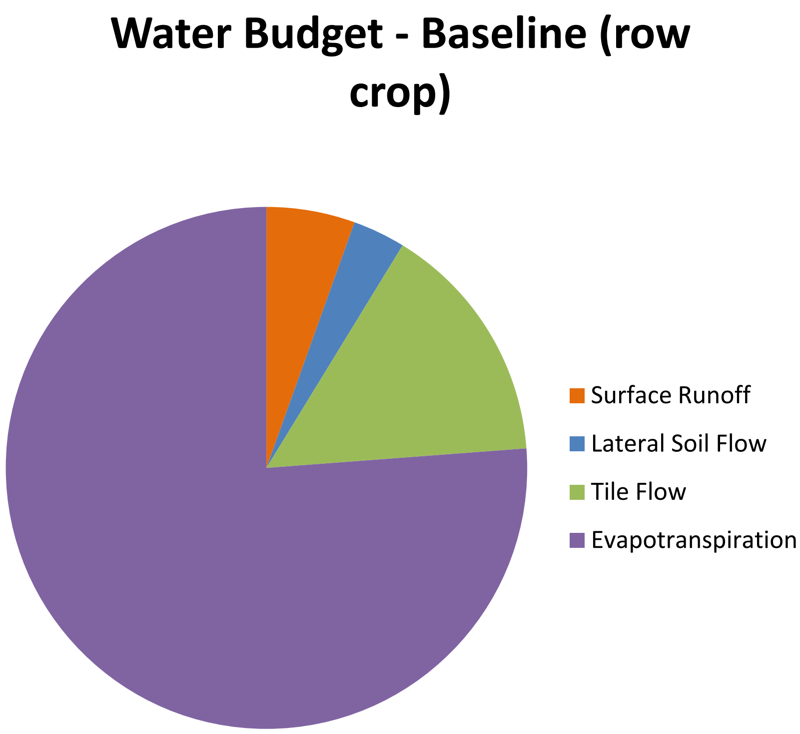
- We combine results from the biophysical and economic models to search for these efficient land-use patterns

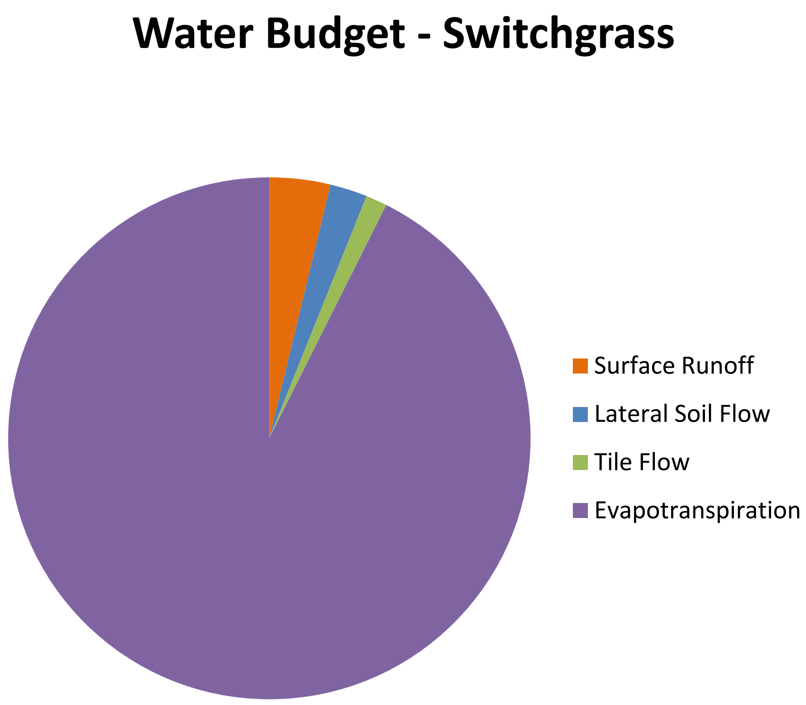
- By finding the maximum TMDL reduction for a fixed economic score, and then varying the economic score over its entire potential range, we trace out the efficiency frontier

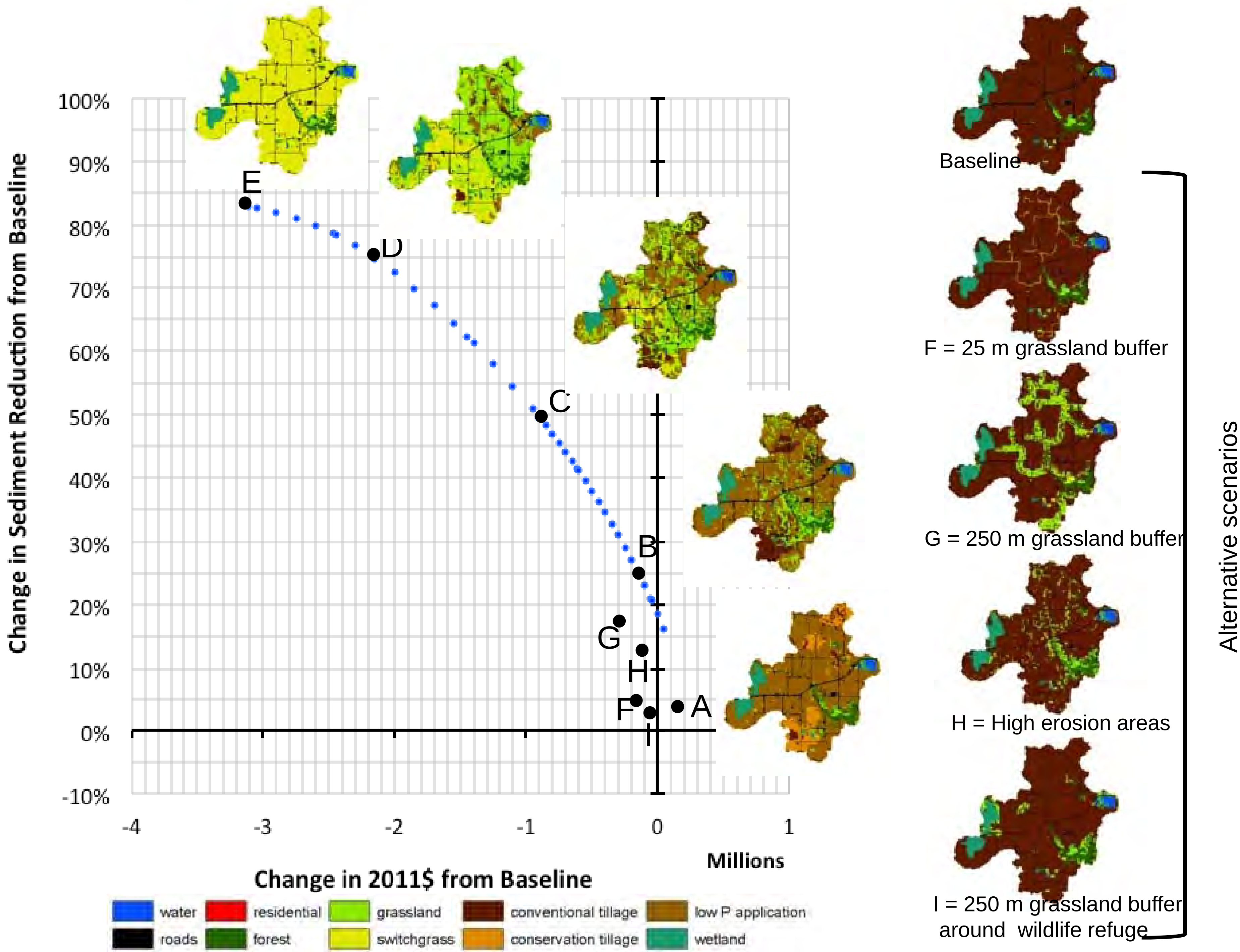


Baseline
Total economic returns = $4.4 million
Max environ. benefit
E
D
75% reduction
C
50% reduction ($100 ha^{-1})
B
25% reduction
A
Max economic returns
100%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-4
-3
-2
-1
0
1
Millions
Change in Sediment Reduction from Baseline
Change in 2011$ from Baseline
water
residential
grassland
conventional tillage
low P application
roads
forest
switchgrass
conservation tillage
wetland

Water Budget Comparison

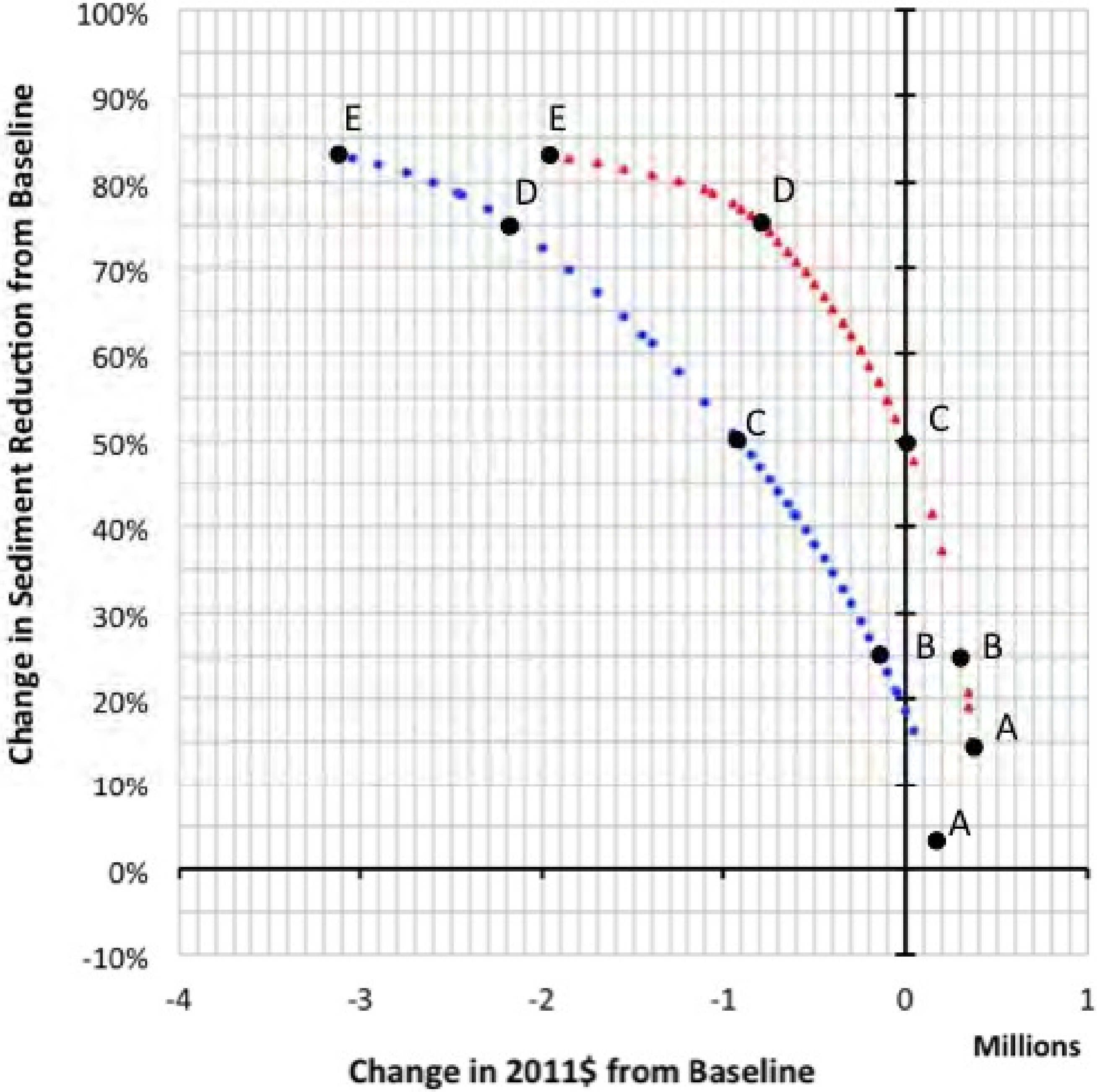






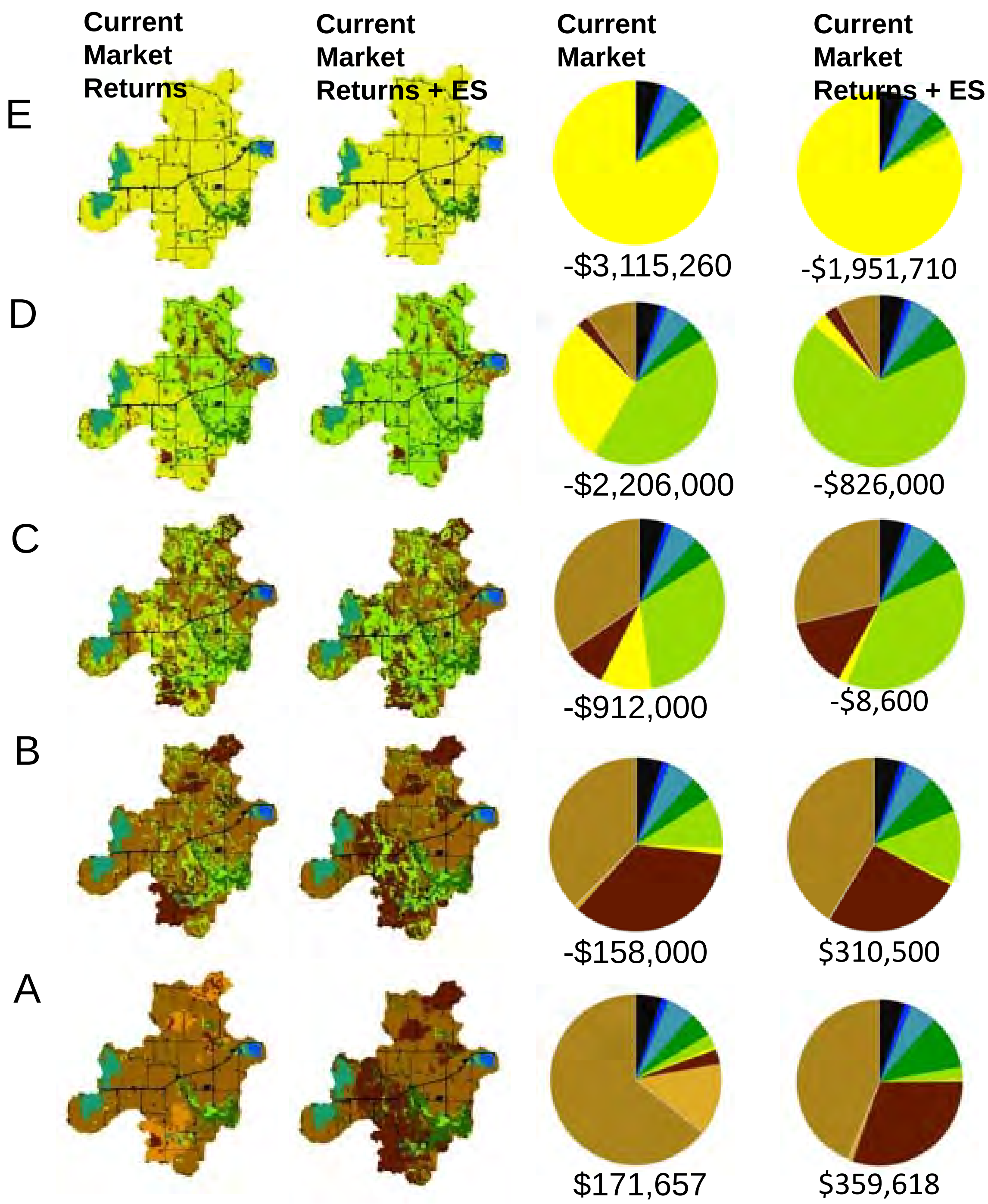
Change in Sediment Reduction from Baseline
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-4
-3
-2
-1
0
1
Millions
Change in 2011$ from Baseline
E
D
C
B
G
H
F
A
I
water
residential
grassland
conventional tillage
low P application
roads
forest
switchgrass
conservation tillage
wetland
Baseline
F = 25 m grassland buffer
G = 250 m grassland buffer
H = High erosion areas
I = 250 m grassland buffer around wildlife refuge
Alternative scenarios

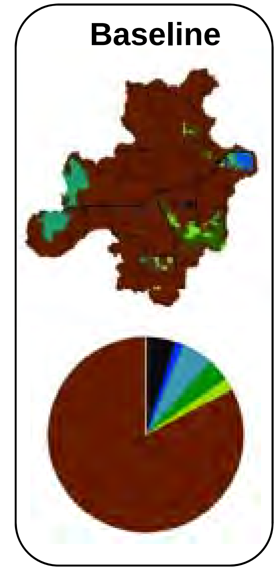
Efficiency frontiers for Sed reduction constrained by market returns and by total value



Adding non-market ecosystem service value:

- carbon sequestration
- Sediment reduction
- Phosphorus reduction

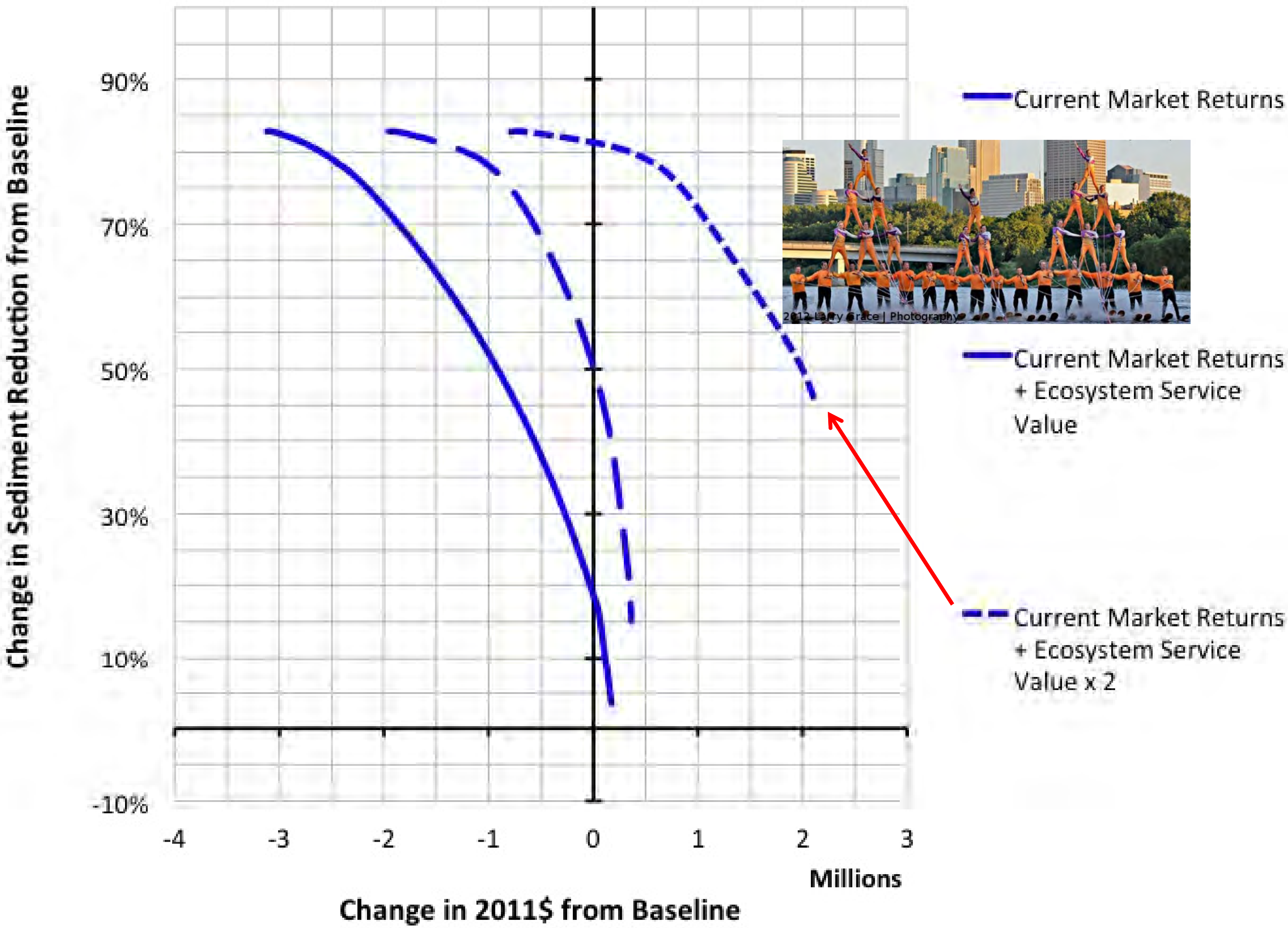


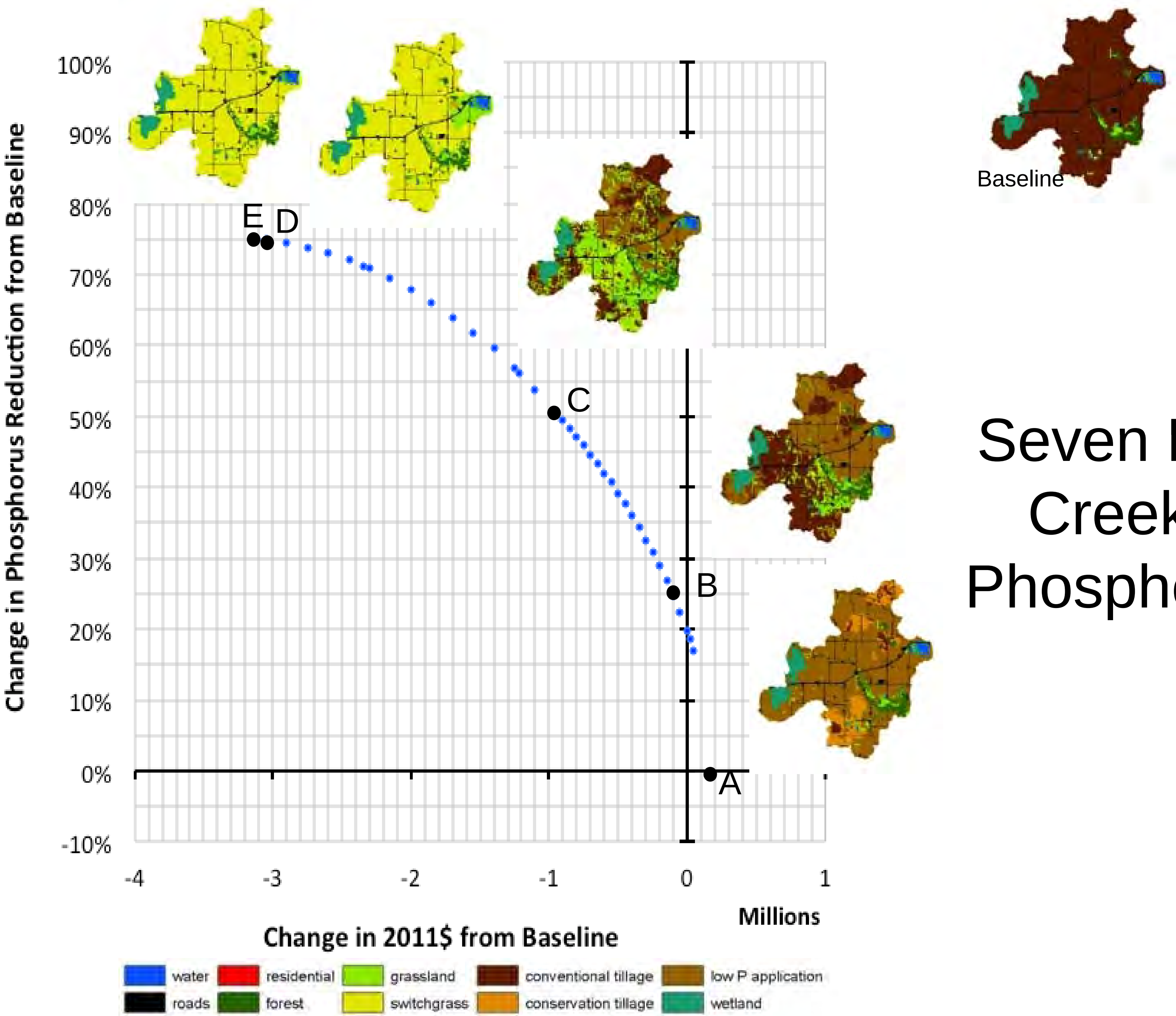


Additional content in final report:

Includes multiple landscape images (and valuation) for different points along various frontiers.

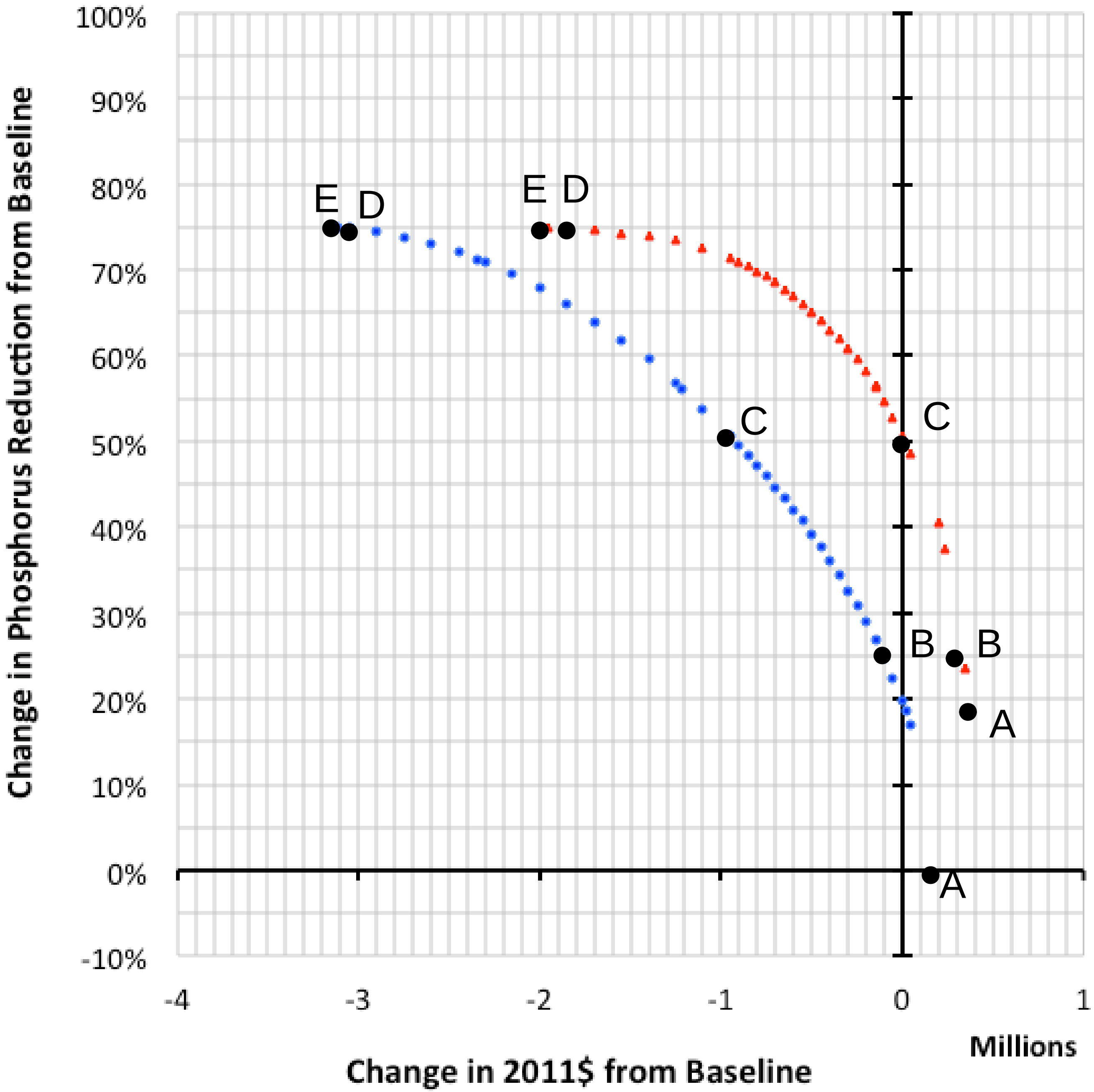
Efficiency frontiers for Sed reduction constrained by market returns and by total value





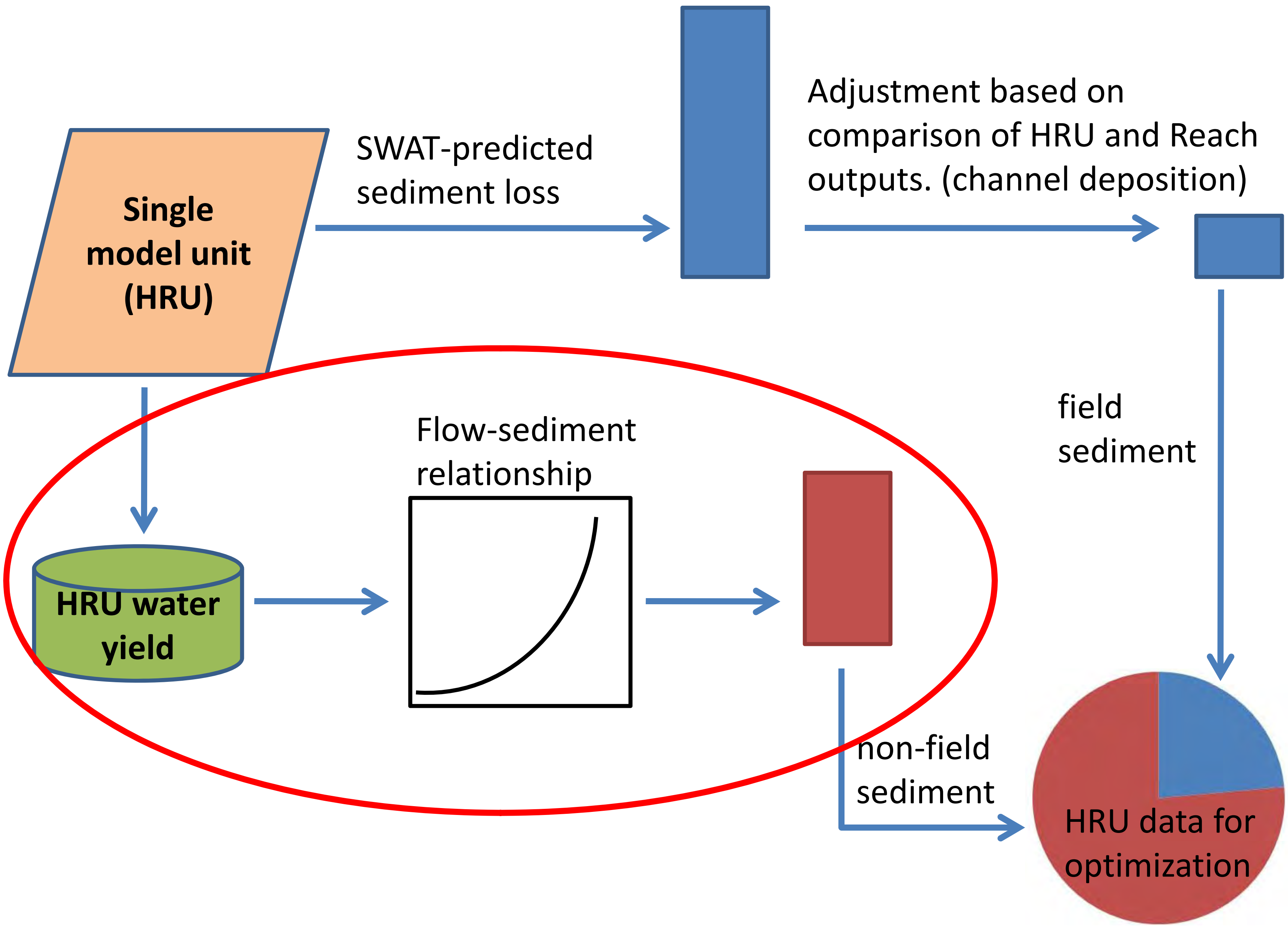
Seven Mile Creek - Phosphorus

Efficiency frontiers for P reduction constrained by market returns and by total value



What's the benefit of considering non-market ecosystem service value?

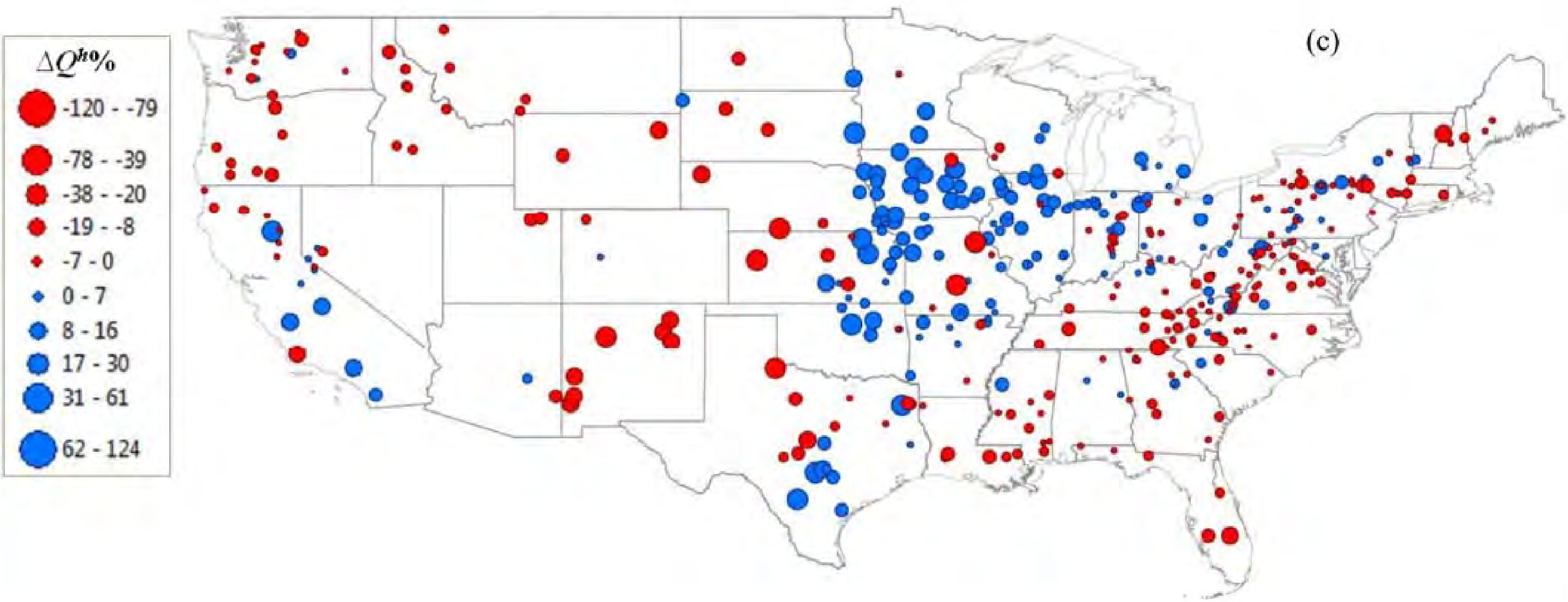
Data preparation schematic for optimization input



Changes in streamflow - climate

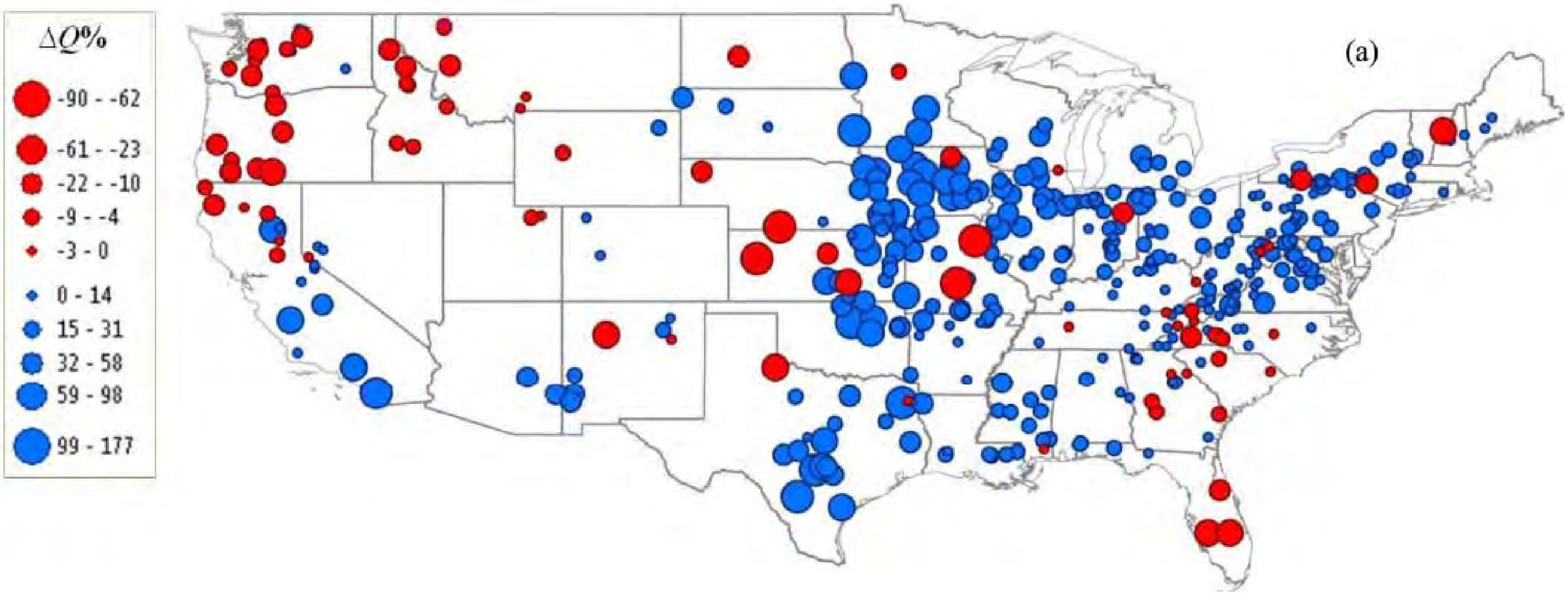
Wang and Hejazi, WRR, 2011

Changes in streamflow - humans

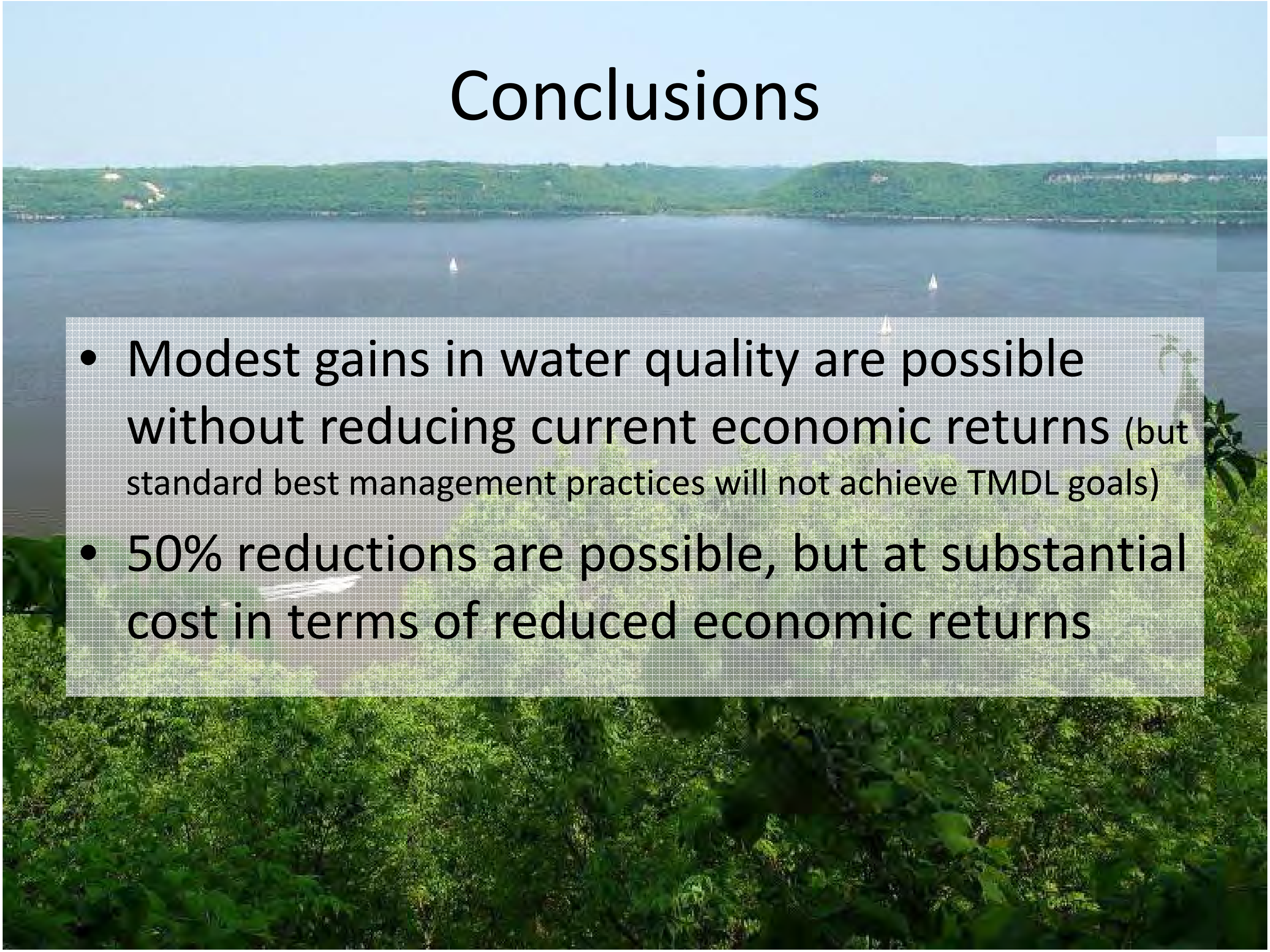


Wang and Hejazi, WRR, 2011

Changes in streamflow - total



Wang and Hejazi, WRR, 2011


Conclusions
• Modest gains in water quality are possible without reducing current economic returns (but standard best management practices will not achieve TMDL goals)
• 50% reductions are possible, but at substantial cost in terms of reduced economic returns

Conclusions

- The failure to incorporate the value of ecosystem services in land use planning can result in poor outcomes
  - Low level of ecosystem services
  - Low value of total goods and services from landscape
- Important to include value of ecosystem services in land use planning and incentives to landowners


Thank you!